“Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)”

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Agronomy

By

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DECLARATION

I, hereby declared that the presented work in the thesis entitled **"Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision Dr. Ujagar Singh Walia working as Professor in the Agronomy School of Agriculture of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE-I

This is to certify that the work reported in the Ph.D. thesis entitled, **"Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** submitted in fulfillment of the requirement for the reward of degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Agronomy, School of Agriculture** is a research work carried out by Mr. Tarun Sharma, 1919662, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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Name of supervisor: Dr. Ujagar Singh Walia

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CERTIFICATE-II

This is to certify that the thesis entitled **"Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** submitted by **"Tarun Sharma (Registration No. 11919662)** to the Lovely Professional University, Phagwara in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Agronomy** has been approved by the Advisory Committee after an oral examination of the student in collaboration with anexternal examiner.

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LIST OF ABBREVIATIONS

Abbreviations		Meaning
%	:	Percentage
@	:	at the rate
°C	:	Degree celcius
C.D.	:	Critical difference
CV	:	Co-efficient of Variation
cm	:	Centimeter
cm^2	:	centimeter square
RCBD	:	Randomized Completely Design
Fig.	:	Figure
T	:	Transplanted
g	:	Gram
ha	:	Hectare
i:e	:	That is
S.	:	Seeded
m	:	meter
No.	:	Number
DM	:	Dry matter
WEY	:	Wheat Equivalent Yield

Abstract

The field experiment on **"Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice-based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** was conducted in two independent experiments at the Agronomy Farm, Lovely Professional University, Phagwara, during *Rabi* season of 2020-21 and 2021-22. Two experiments were conducted in RBD with 14 treatments in each in order to meet the objectives of project study. Due to similar morphological growth habits and seed shedding behaviour, the *Phalaris minor's* seed bank is more in the field of wheat. By replacing the crop (wheat) with other *Rabi* season crops, the *Phalaris minor's* seed bank can be reduced. This investigation revealed that rice-berseem, rice-oats, rice-potato-radish and rice-potato-carrot cropping systems completely eliminated the seed bank of *Phalaris minor* due to continuous practice of these systems at least for two consecutive years. The count (per sq.m.) of *P.minor* and dry matter of *Phalaris mino*r (q/ha) were significantly less in rice-berseem, rice-oats, rice-potato-radish and rice-potato-carrot cropping systems as compared with other crops because of repeated cutting of berseem and oats. Intercultural operations in potato like earthing up and digging also resulted in elimination of *Phalaris mino*r. While oil seed cropping systems like rice-gobhi sarson and rice-African sarson showed supressing effect but unable to provide complete eradication of soil seed bank of *Phalaris mino*r. The cropping system of rice-barley and rice-lentil partially controlled the infestation of *Phalaris minor*. Rice-potato-carrot and rice-potato-radish cropping system showed maximum WEY (wheat equivalent yield) (i.e., 203.51 q/ha and 207.42 q/ha) followed by rice-oats (136.04 q/ha). Berseem, oats, potato-radish and potato-carrot had more smothering effect on *Phalaris minor* as compared to oil seed crops.

In the second experiment, intercropping was done which consist of wheat weed free and wheat weedy, gobhi sarson, African sarson, lentil, fenugreek, fennel and dill seeds. The grain yield and plant height of wheat varied significantly among different *Rabi* intercrops sown in bed planted wheat. Wheat as sole crop gave significantly higher grain yield as compared to wheat intercropped with various *Rabi* crops. Wheat as sole showed more significant production of dry matter. The yield components and yield of wheat compared to all intercropping systems except with fennel. Significantly less count and DM (dry matter) accumulation of *Phalaris minor* was observed in intercropping of wheat with fennel and dill seed. These cropping systems enhanced the wheat grain yield as compared with other cropping system. Wheat as sole crop gave the maximum yield but highest equivalent yield was found in intercropping of wheat along with medicinal crops dill seed and fennel. The maximum equivalent yield of wheat (81.44 q/ha & 79.42 q/ha) was obtained in dil seed and fennel intercropping system during 2020-21 as compared to 64.63 q/ha in sole wheat. During the second year (2021-22), the dil seed gave 84.99 q/ha and fennel gave 82.47 q/ha wheat equivalent yield whereas wheat as sole crop gave 65.91 q/ha grain yield. Among Brassica crops, the intercropping of wheat with gobhi sarson also decreased the count and dry matter of *Phalaris minor* but it also decreased yield of wheat crop. Brassica crops due to their more height are better competitor for all growth factors, thus reduce more yield of main crop (wheat) than other tried intercrops. On the other hand lentil, dil seed, fenugreek and fennel are less competitor and hence reduction in wheat grain yields are comparatively less than brassisca crops. The highest wheat yield reduction was recorded in wheat weedy (44.14%), followed by gobhi sarson, 36.06%. The minimum percentage decrease was found in lentil crop (21.63%). Intercropping of wheat with African sarson, fenugreek, fennel and dil seed weedy treatments also decreased wheat yield by 32.76%, 25.48%, 25.56% and 23.71% respectively over weed free.

Keywords: Soil seed bank, *Phlaris minor*, intercropping, wheat equivalent yield.

Chapter 1 INTRODUCTION

Wheat **(Triticum *aestivum* L.*)*** is furthermost significant crop among cereals which is the major source of calories for human diet. Wheat belongs to Poaceae family and is the member of *Triticeae* tribe. Wheat is the primary food for the major population on the globe. Wheat contributes 20% among all dietary calories and protein worldwide. Wheat accounts 53% of the total harvested area and 50% of production (Figueroa *et al*., 2018). It is the important source of dietary nutrients and provides 20% of daily protein and energy. In food-based industries, wheat is the primary ingredient of many food products. The by-products of wheat are used as a feed for animals which are rich in nutrients. Wheat is rich in gluten content which helps in making breads and baking products. Wheat requires cool climate for germination and initial growth followed by sunny days for their proper growth and reproductive development. Wheat is grown mainly in Indo-Gangetic plains but can be cultivated in many parts of India during *Rabi* season. It is one of the options to enhance the economic status of Indian farmers.

India export wheat to different countries like Nepal, Sri Lanka, Bangladesh, Somalia and UAE. In India, wheat is cultivated in Punjab, U.P., Bihar, Rajasthan, M.P, Haryana, Gujarat and Maharashtra. India ranks first globally in terms of cultivated area. India contributes 13.6% in wheat production globally. The total world's area under wheat cultivation is 218.54 m ha during 2021-2022 with the production of 778.6 million metric tons. Globally the entire area under cultivation of wheat was highest in India which was 31.36 m ha and production is 107.59 m ha. (FAO STAT) 2021-2021. The area under wheat cultivation in Punjab was 35.30 L ha with production of 171.85 Lt and average yield of 48.68 q/ha (Anonymous 2021-22).

Wheat belongs to the genus *Triticum* of Poaceae family. There are about 25 species of wheat which have been found in the world. Out of which *Triticum aestivum* (Bread wheat) and *Triticum durum* (Emmer wheat) are commercially cultivated in India. *Triticum aestivum* is mostly cultivated on large scale among other species and it is hexaploid having chromosome number 2n=42. *Triticum durum* is also called macaroni wheat having 28 chromosome numbers. Wheat requires the cool climate at the vegetative stage where as warm temperature is needed during the maturity stage and the ideal temperature of 20 to 32ºC for its growth & development.Wheat requires low temperature during the initial stages because high temperature at early phases causes poor tillering which leads to early heading and low yield. For the development of more fertile tillers, the optimum temperature is 10 to 30°C. But at the time of ripening, it requires slightly high temperature, however very high temperature at maturity results in shriveled grains. High temperatures during grain maturation originally increased grain filling rate but decreased final grain weight. High soil temperature during the primordial formation reduces the number of spikelets. High humidity invites the attack of pest and diseases. Although the different types of soils can be used to grow wheat but soils having good water retention capacity and proper drainage are good for its growth. The pH requirement for the growth of wheat is 5.5 to 7.0. Wheat is medium tolerant to soil salinity. The average height of wheat is 1.25 m to 1.75 m. The semi dwarf varieties having average height of 90 cm which also depends upon genetic makeup and management practices. Wheat has seminal roots that appear shortly after germination that provides nutrition and moisture to the plant at the early growth stages. Root can penetrate 75 cm deep in the soils or even more.

There are different agronomic techniques which govern the grain yield. Weeds population in wheat crop depends upon sowing date and planting patterns. There are different techniques for wheat sowing like bed sowing, flat sowing and cross sowing etc. For controlling weeds, raised bed method is suitable as this method reduces the weed population due to deep burial of weed seeds as well as it requires less input. Moreover, it helps to improve water use efficiency, decrease lodging and minimizes insect, pest and disease attack. In conventional methods, wheat seeds are broadcasted or drilled into a flat surface in rows. In cross sowing methods, wheat seeds are drilled in closely spaced rows of 15-20 cm apart on the flat surface in both directions i.e., sowing with half the recommended seed rate is one direction and other seeds are sown in the opposite direction. In this method of planting, there is optimum plant spacing resulting in more smothering of weeds. So, cross sowing is very important cultural technique for smothering weeds of wheat crop.

Beds are made at 67.5 cm spacing and top width of bed is 37.5 cm and the distance between two beds is 30 cm (furrow) and two rows of wheat can be planted on the tops of bed. Bed planters are available in the market which prepare the beds and sow the crop in one strip only. The crop is irrigated in furrows. This method provides the better water management and drainage as compared to the previous flood irrigation technique used in conventional method. This method was firstly adopted by farmers of northwest Mexico. It reduces the cost of cultivation by increasing the nitrogen use efficiency. Phosphorous use efficiency is greater in raised bed system as compare to flat sowing. Raised bed technology increased the root mass density of plant in surface and sub-surface soil layers. The crust issue on the surface of soil is eliminated & physical condition of soil gets improved. Lodging is the main problem in various crops which decrease the crop yield. Various techniques have been used to tackle the problem of lodging. Lodging during critical stages such as flowering and filling of grain, reduces grain yield drastically. Bed planting technique is more beneficial in clayey soils with more water holding capacity as compared to flat sowing method. Raised bed technology not only saves the irrigation water but also prevents lodging due to stronger root system, stout culms and due to more aeration. Raised bed reduces the lodging in the wheat crop to a great extent. It saves about 20-30% of water as compare to flat sowing. Raised bed technology has great potential to increase water productivity of field crops. Apart from these advantages, this technology is highly beneficial in heavy soils with less percolation rates as under such prevailing conditions, crop is not harmed with excess water.

Weeds are those unwanted plants which grow in the field out of their space. Moisture, light, nutrients and space are those resources for which weeds compete with wheat. Weeds are host of many insects and diseases. Weeds decrease grain yield of crops to excessive range. If population of weeds are more as compare to major crop, it affects the quality and quantity of crop yield (Halford *et al*., 2001). They reduce the crop yield by providing competition for applied inputs, having allelopathy effect and act as alternate host of different insect and disease. Weeds are of different types viz. sedges, broad-leaf weeds and grass family weeds. The *Phalaris minor* Retz. (Littleseed canarygrass), *Avena ludoviciana* (Wild oats), *Poa annua* are the major grass weeds of wheat. In Indo-gangetic plains of India, the prevailing weed is *P. minor*. Rice-wheat cropping system has covered about 40 per cent area of country. *P.minor* reduces the grain yield of wheat because it competes with wheat for resources (Bhan and Kumar, 1998).

Phalaris minor is one of the noxious weed which is a monocot plant belonging to Poaceae family. It has similar growth habitat with wheat crop and difficult to identify in the initial stages between wheat and *P.minor*. The *P.minor* has pinkish stem at base of plant where as the basal node of wheat plant is green in colour. The *Phalaris minor* has soft texture on leaves and it is ligh green in colour. It produces about 3000-4000 seeds per plant. There were about 22 species of *P. minor* found in the world. It was reported that from North Africa, the Mexican wheat varieties are the main source from which seeds of *P.minor* came to India. Research experiments indicated that *P.minor* reduces the wheat yield upto 20-25% but in heavy infestation yield loss goes up to 80% (Franke *et al.*,(2007). Wheat provides the favourable ecological condition for the growth of *P.minor* as optimum temperature for their growth and development is same. The seeds of this weed can survive in primary dormancy for about 3-4 months and in secondary dormancy for up to 12 months. Before crop harvest, 80-90% seeds are shed in field by *P.minor* and this is the reason that *P.minor* is considered to be highly persistent in nature.

There are various methods for the control of weeds like preventive, biological, chemical, mechanical and IWM. Also adoption of cultural practices, which include crop rotation, intercropping, adjusting sowing dates, planting pattern, seed rate, spacing, irrigation methods and placement of fertilizer etc helps to reduce *P.minor* populations in wheat crop. Cultural methods provide the favourable conditions to wheat crop and suppress the growth of weeds. Several cultural practices like proper fertilizer placement and efficient irrigation application methods helps in providing favourable environment to crop. These types of practices help in controlling/reducing growth of weeds if they used properly. Cultural methods help in reducing the intensity of weeds but alone cannot control weeds. Immediate control is not possible with cultural practices. The weeds especially perennial and problematic can be controlled effectively by adopting crop rotations. Perennial weeds can be controlled by transplanting rice. IWM helps to provide better weed control options.

Intercropping is an important agronomic practices for controlling weeds and decreases the use of synthetic herbicides (Banik *et al*., 2006). By growing the different crops at the same time at the same place is known as intercropping. The cropping intensity of upland areas is very low due to mono-cropping system. Mono-cropping declines the soil fertility. In these conditions, the stability has been achieved through crop substitution and intercropping. For maintaining the soil fertility, it is very important to grow two or three crops as mixed or intercropping. In intercropping, the main principle is judicious selection of crops. The crop should be short duration and having same ecological requirements as of main crop. It should have minimum competition with main crop. To increase net profit, wheat crop should be intercroped with other *Rabi* season crop such as Barley, Mustard, Lentil, Linseed, Fennel, Gram and Dil seed etc. Replacing wheat with potato/berseem/oats etc helps to increase profitability of farmer as compared to sole wheat.

Wheat crop is also intercropped with pulses like lentil, chickpea etc. Pulses belong to Fabaceae family. These are the most important crops after cereals. Pulses are indispensable crops. It is used as both food and fodder. Atmospheric nitrogen is fixed by pulses in the soil and improves the soil fertility. Legumes require high amount of P, Ca, Cu and Zn. It is the source of protein and fiber. Pulses are important component of cropping system and are more suitable for intercropping. Lentil ranks fourth important pulse in leguminous crops. Lentil requires cool climate. It is a long day crop. Required temperature for the growth and development of lentil is 15-20ºC. If the temperature is less than 10ºC, germination of crop is delayed. It is mostly cultivated in loamy to heavy black soils. The pH of soil should be 5.5 to 8.0. This crop does not tolerate water logging. Wheat can be intercropped with mustard crop also which is the oldest cultivated plant in human civilization. Mustard belongs to Cruciferae family having genus Brassica. It is cultivated in both the subtropical and tropical countries. It has been grown all over the world but mainly confined to India, China, Germany, USA and France etc. It is cultivated in alluvial, red loams and black soils. It does not withstand waterlogging. It is intercropped with wheat crop in various ratios like 4:1.

Crop rotation is growing of different crops at the particular land in defined order. There are certain principles of crop rotation like after growing tap root crops, grow non-leguminous crops and then follow leguminous crops for fixing atmospheric nitrogen. Both methods help to maintain the soil fertility. They reduce the growth and development of weeds as well as attack of insect pest and diseases. Crop rotation improve the physical properties as well as chemical properties of soil. Certain type of nutrients are depleted from the soil every year due to mono cropping.

Crop-rotation improves structure of soil by improving soil aggregates and enhance O.M concentration in the soil. As per the crop weed association phenomenon, typical type of weeds is associated with specific crop. For example, *E. crusagalli* related with rice whereas *P. minor* with wheat. So, the problem of these weeds can be eliminated by rotating these crops with other crops during the respective seasons. Weeds also affect the quantity and quality of crop. Under prevailing situations, controlling the weeds with the help of herbicides is economical. But due to continuous use of herbicides, weeds develop resistance which is the serious environment concerns. Integrated method is the best method for controlling the weeds. Cultural practices along with chemical practice are being widely considered by the researchers.

The major source of weed infestations is seed banks of weeds during the coming years. Rice-wheat cropping system dominates in Punjab State. Two major weeds of this system i.e., *Phalaris minor* and *Echinochloa crusgalli* of wheat & rice respectively shed seeds about 90% before crop harvest and hence enrich soil seed bank of weeds. Vegetative propagules and viable seeds are present on and in the soil which become germinated when conditions are favourable (Shrestha *et al*., 2002). Crop rotation significantly reduces the soil seed bank status and it is effective as compared with other cultural practices of weed control methods (Cardina *et al*., 2002). Population of weeds were significantly controlled by two years of crop sequences (Bellinder *et al*., 2004).

It has been reported by Chahal *et al*., 2005 that the seed bank of *Phalaris minor* can be nearly eliminated by changing wheat cropping system with fodder viz. berseem-oats or potato continuous to two years. In case of fodder crops, the plants of *Phalaris minor* will be cut with fodder before seed setting resulting in no addition of seeds in seed bank of weeds in soil for the 1st year and during 2nd year only few seeds of *Phalaris minor* lying in the deeper depths of soil will show germination. Also all the grown up seedlings of *P.minor* will be destroyed with the digging of potato crop resulting in no addition of seeds of this weed in soil. Also, replacement of which with rapeseed and mustard crops helps to smother *Phalaris minor* due to their quick growing habits as well as broader leaves. Hence the present investigation entitled "**Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice-based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** was conducted at research farm of LPU with following objectives.

Objectives

- To study soil seed bank status of *Phalaris minor* as influenced by different crops.
- To study wheat equivalent yield of different *Rabi* season crops.
- To study smothering potential of different intercrops on *Phalaris minor*.
- To find out most profitable cropping system.

Chapter 2 REVIEW OF LITERATURE

The research work refers to **"Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice-based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** has been reviewed & summarized under following sub heads:

2.1 Yield loss due to weeds
2.2 Effect of crop-rotation on weed growth
2.3 *Phalaris minor* seed bank in soil as influenced by crop rotation
2.4 Effect of different sowing methods of wheat
2.5 Effect of intercropping on *Phalaris minor*
2.6 Grain equivalent yield
2.7 Quality parameters of wheat

2.1 Yield loss due to weeds

Soltani *et al*., (2022) described that in Ontario glyphosate-resistant weed was not controlled by herbicides. It reduced the profit value by $290M annually. By the application of herbicides, the cost of cultivation of farm became increased by $28M. The farm yield was reduced up to 95%.

Farahat *et al*., (2022) explained in experimental study that based on a 10% yield loss, 63 to 79 DAS was the critical period of weeds control in barley. Weeds reduced the crop yield if critical period was passed out. Weeds competed with main crop for all resources like nutrients, moisture and light, as a result agricultural yield had been reduced.

Flessner *et al*., (2021) reviewed that the potential loss of spring wheat is estimated to be cost of US$1.14 billion in U.S. and Canada. This analyses in yield loss are greater than some earlier estimates, which suggests that weeds are becoming an increasingly serious issue.

Raj *et al*., (2020) reported that both *Phalaris minor* and wheat are grassy monocot plants, due to which both had similar competition for nutrients (Nitrogen) but had differential use of nitrogen. *Phalaris minor* decreased the wheat grain yield. The density of *P. minor* (80 plants/m^2) also decreased the tillers and dry matter of wheat crop.

Gharde *et al*., (2018) noted that weeds decreased yield of crop and its economic loss. Maximum yield losses were observed in soybean followed by groundnut rice, maize (18-65%). Net profit was reduced in different crops as 11 billion in pearl millet (27.6%), sorghum (25.1%), sesame (23.7%), green gram (30.8%) and transplanted rice (13.8%).

Amare (2014) noted that the weed density was directly influenced by weed management practices and he reported that wheat grain yield reduction ranges from 57.6% to 73.2% due to weed competition. The various weeds of winter season were *Avena fatua*, *Conolvulvus arvensis*, and *Chenopodium album*.

Singh *et al*., (2013) noticed that there was severe yield loss up to 45% due to biotic stress such as weeds provided in rapeseed-mustard. Mustard suffered from more weed competition. The critical stage for mustard is between 20-40 DAS. The weeds were suppressed by applying herbicide along with hand weeding. It was very effective in suppressing the weeds and gave significant improvement in crop yield.

Kaur *et al*., (2012) found that population of *Phalaris minor* was increased to thresh hold level, the production potential of wheat was decreased. The dry matter production, total tillers & effective tillers, yield and yield attributes of wheat were decreased as increase in the density of *Phalaris minor*. It had been observed that the presence of 15 plants per square meter *Phalaris minor* significantly decreased the 14% of wheat grain yield.

Hesammi *et al*., (2011) noted that the *Phalaris minor* with population of 80 plants per meter square significantly decreased yield of wheat crop. It was reported that grain yield were decreased up to 18 to 19% as the population of *P. minor* was 20 to 80 plants per square meter. The *Phalaris minor* had no effect on the number of grains per spike in wheat crop.

Sharma *et al*., (2009) noted that the application of oxyfluorfen increased the seed yield of mustard by reducing the dry matter of weeds. Weeds took less amount of NPK from the oxyfluorfen treated plot. Highest uptake of nutrients by main crop was observed in oxyfluorfen treated plot followed by pendimethalin treated plot.

Montazeri *et al*., (2007) reported that *Phalaris minor*, *Avena ludoviciana* and *Sinapis arvensis* were the major weeds of winter wheat. It had been observed that there was no effect on height due to *Phalaris minor*. But *Phalaris minor* (29 to 39 plants/m$^{2)}$ significantly reduced the test weight (1000 grain weight) and decreased the grain yield from 18 to 19%. Other two weeds (*Avena ludoviciana* and *Sinapis arvensis*) significantly reduced the wheat grain yield from 12.5 to 74%.

Oad *et al*., (2007) observed on the height of plant, no. of tillers, effective tillers, grain yield, seed index and wheat biomass. They observed that yield losses due to *Phalaris minor* infestation was 35.33%, followed by *Avena fatua* (36.48%), *Chenopodium album* (39.95%), and *Melilotus alba* (24.01%). The yield loss ranged from 24% to 39% in wheat crop due to weed competiton.

Khan *et al*., (2006) studied on grassy weed in wheat crop reduced 30% of yield in wheat, however broadleaf reduced 24% of yield and mix stand reduced 48% of wheat yield. Results revealed that there was negative correlation between weeds and wheat yield. Variability in weeds accounted 22% of variability in wheat yield.

Oerke (2006) observed that the incidence of pests on main crop was due to presence of weeds which had similar growth habitat with main crop. The total loss in yield by weeds were 50% in grains of wheat and 80% in cotton production. The weeds reduced the crop yield which could be controlled mechanically or chemically i.e., with application of weedicide.

Ranjit *et al*., (2006) noted that yield and quality of wheat had a negative impact of *Phalaris minor* on it. Growing of rice followed by wheat, enhance the no. of *P. minor* and it was major weed of wheat crop and significantly reduced the wheat yield from 10 to 50 percent.

Duary *et al*., (2005) concluded that the wheat yield was decreased as the densities of *P.minor* increased from 0 to 200/m^2. Results revealed that wheat yield and densities of *P.minor* had hyperbolic relationships. Both the observed and predicted yield losses were close. For the single season, the economic threshold of *Phalaris minor* for herbicide isoproturon was calculated as 13 to 19.7/ m^2.

Johnson *et al*., (2004) studied the effects of differing periods of weed control in rice of direct seeding field. There was 49% grain yield loss due to weeds. Weeds provided competition to crops during critical stages of crop growth. Weeds had negligible or no effect on crop yield when compete either before or after critical stages.

Kim *et al*., (2002) reported that the *Striga hermonthica* was one of the important parasitic weeds of cereals in Africa. They conducted the experiment between tolerant varieties and non-tolerant varieties. In non-tolerant varieties the reduction of yield was up to 79%. But tolerant varieties suffered less yield loss. They produced 2-2.5 times more yield than susceptible varieties.

Walia *et al.*, (1997) studied on the increasing the population of weed and decreasing the yield of wheat. Population of a *P.minor* viz. 60-70 plants/m^2 decreased10 per cent in wheat yield. However, wheat yield losses exceeded 30-50 per cent with 250-500 plants/m^2 of *P minor.*

Afentouli *et al*., (1996) studied the densities of *P.minor* or *P.brachystachys* (76 plants/m^2) was not significantly affected the wheat grain yield but it was reduced by 36 to 39 per cent by the increasing the population of *P.minor* to 304 plants/m^2.

Khera *et al* (1995) noticed dry matter accumulation and yield of wheat was decreased by 21 to 23 percent as the density of *Phalaris minor* was increased up to 40 plants/m^2. *Phalaris minor* substantially reduced the yield of wheat as 6 plants of *Phalaris minor* did not allow to grow 10 plants of wheat.

2.2 Effect of crop-rotation on weed growth:

Saulic *et al*., (2022) observed from a long-term experiment on crop-rotations having different crops in the order have a major impact on weed population maintenance. While chemical fertilizers would alter the different properties (chemical & physical) of the soil and unbalance the diversity of the plant population, decreased the density of weeds and also decreased the cost of crop production. Crop rotation was completely failed when green manures or compost had large weed seed infestations.

Wickramasinghe *et al*., (2022) reported in the research study that the first cycle of the rice crop phase under Integrated Nutrient Management (INM) had a high weed density. However, under INM, both crop phases (rice and maize) in the second cycle had low weed densities. In the Yala (from May to September) seasons, crop rotation was associated with a higher density of sedges, and both seasons' mono-cropping was dominated by grasses. The nutrient management strategies had no effect on the biomass of grass, however only synthetic fertilizer boosted the biomass of sedges. Both nutrient management strategies had significantly increased the dry matter of maize and decreased the population of weed in the second cycle. In general, the chemical fertilizers was reduced by 50% and adding organic matter significantly helped in controlling the weed in both rice and maize crops.

Jalli *et al*., (2021) noted the positive impact of crop-rotation. Continuous growing of different crops in different crop-rotation forsix years had decreased root diseases of stem and DI (disease index) become lowest due to different varieties. Neither tillage nor crop-rotation affected the wheat pest midge *Sitodiplosis mosellana* (wheat midge). The diversified crop rotations such as growing of cereals, including oilseed crops and nitrogen fixing legumes enrich the nutrients and boost yield. Crop rotation decreased the severity of plant diseases in wheat, having more impact due to zero tillage system.

Shahzad *et al*., (2016) found that the rotation of sorghum-wheat significantly decreased the weed infestation. Bed sowing of wheat significantly increased the wheat yield by intercropping with mung.

Koochaki *et al*., (2009) studied on weed seeds population which was about 6300 seeds/m^2 in continuous winter which was higher than the treatment in which wheat was kept as one crop in the crop rotation (5000 seeds/m^2). In continuous winter wheat, annual grass weeds were more but in sugarbeet-winter wheat, broadleaf weeds were abundant. There were about 90% grass and sedges weed in continuous winter wheat and only 43% of total weed density in sugarbeet-winter wheat rotation. In wheat crop, the seed bank of weeds were reduced due to rotation of these crops.

Om *et al*., (2004) recorded the biology of *P.minor* and its management in rice-wheat cropping system. Cultural practices significantly controlled biotypes of *P. minor*. Results revealed that crop rotation decreased the seed dynamics, growth pattern and density of *Phalaris minor* in main crop wheat.

Brar (2002) observed crop-rotation the change in weed spectrum and made the conditions unfavorable for *Phalaris minor*. Rotation of wheat crop with gobhi sarson, barseem or potato in rice-wheat cropping system for two to three years significantly decreased the density of *Phalaris minor* as well as its seed bank status in soil.

Cardina *et al*., (2002) observed that crop-rotation and tillage showed more significant interaction. The seedbank density of broad leaf weeds was lower in crop rotation system than mono cropping.

Mahajan *et al*., (2002) observed that integration of herbicides along with cultural methods like crop rotation, sowing time and methods, seed rate, spacing significantly decreased the population of *Phalaris minor* in wheat.

Buhler *et al*., (2001) noted that crop rotation of corn-soybean-corn significantly decreased weed density each year. Results revealed that 90% of weed seeds of foxtail decreased in 1st year of maize and remained same during the following years of soybean. Soil profile at the upper layer of 10 cm the weed seeds of foxtail were significantly increased during next rotation of oat and reseeded with hay species.

Doucet *et al*., (1999) noted that crop rotation reduced the weed density and maintained species density. The weed density in crop rotation was accounted 5.5% where as other weed management strategies accounted 37.9% of weed population. Crop rotation decreased the weed population depending upon the crop.

Hassanein *et al.,* (1999) studied on the consequence of crop rotations. Crop rotation with wheat controlled the wild oat and other weed in middle Egypt. He observed that cropping sequence of berseem-berseem-wheat gave complete eradication of grass weeds like wild oat or canary grass. This crop rotation gave maximum grain yield when compared with the crop sequence of wheat-wheat-wheat.

Marenco *et al*., (1999) studied on effect of crop rotation on weed population, leaf cholophyll concentration, yield and yield attributes of rice crop. Crop rotation of rice with cowpea reduced the weed density. In the first year, crop rotation had no impact on weed density and dry matter accumulation of weed but in second year weed population decreased and chlorophyll content increased.

Banga *et al*., (1997) observed that continuous practice of same cropping system (rice-wheat), considerably enhanced density of *P.minor*. Crop-rotation when changed with substitute crops like fodder crop berseem, tuber crop potato, winter maize for two to three years, the density of *Phalaris minor* was significantly decreased. The herbicide isoproturon was not used which increased wheat yield by 10-25 q/ha.

Martin *et al*., (1993) found that continuous growing of wheat from third to fourth year significantly increased the population of weeds and reduced the wheat yield. The wheat-sorghum crop rotation significantly decreased the weed seed bank.

Ball (1992) noted that *Phalaris minor* had significantly decreased the wheat grain yield. The seed bank status of *Phalaris minor* in soil largely determines its potential density that will subsequently interfere with wheat crops during growing season. *Phalaris minor* was controlled by cultural management as changing the cropping system was one of the method of it. By changing the cropping system as introduced diversified crops under rice-wheat cropping system changed the weed spectrum and created unfavorable soil conditions for *Phalaris minor*. Cropping system with had dissimilar life cycles as compared with *P.minor* and also different cultivation practices which break down the cycle of weeds due to changes in the environmental conditions and become the most effective control measure.

2.3 Weed seed bank in soil as influenced by crop rotation

Hosseini *et al*., (2014) noted that soil weed seed bank from cultivated crop lands and fallow lands. The population of weed seed bank in soil ranged from 52779 seeds per square meter in non-crop lands to 9906 seeds per square meter in crop field. The rotations were wheat, wheat-sugarbeet and wheat-chickpea. *Eragrostis cilianensis* and *Roemeria refracta* were the two main weed species that discovered. Result revealed that different species of weeds were suited to particular crop successions and levels of disturbance. Weed species richness, diversity in soil depths and seed bank abundance were extremely dependent on disturbance levels. Results revealed that agricultural practices control the weed population by cropping sequences or disturbance levels.

Chahal *et al*., (2005) reported that *P. minor's* seeds in soil bank could be eliminated by replacing wheat with berseen or potato for two years and these values were significantly less than wheat treated with herbicide. They also reported that Brassica crops have more smothering potential which significantly decreased dry matter of *P. minor* than that from wheat crop.

Bellinder *et al*., (2004) found that crop-rotation & its influence on weed seed bank. The rotation of crops was two years with alfalfa, clover, rye and sweet corn. Results showed that weed density was increased with rye crop while seed density decreased with sweet corn. Legume crops also decline the seed density. The rye cover crop was not allowed to deter seed return and recruitment to the seedbank as it was done by legumes.

Cardina *et al*., (2002) reported interaction of crop-rotation and ploughing (tillage) with weed seed bank. Result showed that crop rotation significant decreased weed species seed bank than tillage systems. Weed density was increased in no tillage system as tillage intensity increased there was decrease in weed density. In the upper layer of soil from 0 to 5cm most of the seeds were found. Data showed that different management of crop and soil had changed the species composition and abundance.

Buhler *et al*., (2001) conducted an experiment in central Iowa for 5 years in a farmer managed field. In the initial, the field was full of weed seeds. Waterhemp and foxtail species were the major weeds as it covered about 80% of weed seeds. For the next three years the cropping system had been changed to corn-soyabean-corn. It was observed that 90% density of foxtail seeds was declined.

Dorado *et al*., (1999) noted that crop-rotations of monoculture-barley, intercropping of barley-vetch and intercropping of barley-sunflower. Under barley/vetch crop rotation, more number of seeds of knotted hedge-parsley were found in the plot. The seeds of spring whitlow grass and mouse-ear cress was superior in the plots also. The barley monoculture had venus-comb where as common lambs' quarters was mostly found in barley-sunflower rotation. The barley/vetch had more diversified weed populations as compared with barley monoculture and the barley/sunflower rotation.

Walker *et al.*, (1999) observed that amount of *P.paradoxa* seed replenishment to the seed bank was dependent on the crop rotation, with large number of seeds (1400-7000 seeds/m^2) returning during the lucerne and chickpea components. The best system, which returned less than 200 seeds/m^2 over three years, involved the combination of dense stands of wheat and barley, and lower herbicide rates.

Jordan *et al*., (1995) noted that corn-soyabean and oat/clover-corn-soyabean-corn stimulated on the weeds like *Abutilon theophrasti* and *Setaria viridis* influenced the seed bank dynamics. Result showed that crop rotation nearly eliminated *Setaria viridis* seed banks whereas *Abutilon theophrasti* seedbanks were less affected.

Hosmani and Meti (1993) found that Johnson grass became major weed in continuous maize then can be controlled by rotating maize with cotton. Crop rotation had different use of patterns in resource competition, allelopathic interference, soil disturbance, and mechanical damages which were used in crop rotation to reduce the size of weed seed banks because these processes limit the spread of weed diversity and create a more diverse environment.

Schreiber *et al*., (1992) conducted an experiment on crop rotation and its interactions with tillage, and herbicide use. Result showed that seeds of Giant foxtail significantly influenced the corn yield as monoculture, corn-soyabean or corn-wheat-soyabean rotation. Growing of corn in soyabean-wheat-corn reduced the Giant foxtail seed. The soil samples had been taken from the different depths revealed that giant foxtail was significantly reduced by crop rotation as in all tillage systems, the maximum reduction was observed in soybean-wheat-corn rotation.

Schreiber (1992) noticed at Purdue University (USA) that giant foxtail seeds were reduced by growing corn along with followed by wheat. No use of herbicides significantly increased seed production of *Avena ludoviciana* annually. Crop rotation reduced 65% soil seed bank of wild oats.

Schweizer *et al*., (1988) concluded that the cropping system of barley/corn/pinto bean/sugarbeet influenced the weed seed reserves in soil. Four successive years of 4 different cropping pattern were used to cultivate these crops in rotation. 90 million seeds of weeds was found at the top layer of soil (25cm). Around 53% of weed seeds was drop in the soil after four-year of different cropping sequence.

Schweizer *et al*., (1984) reported that growing of corn along with spray of atrazine reduced the weed seeds. Initially, soil profile at the top of 25 cm contained roughly 1.3 billion weed seeds per hectare. The seeds of weeds like redroot and lambsquarters was decreased by 99 and 94%

respectively, after the sixth cropping year. During the first five years where atrazine was treated annually, very few weeds developed seeds, and none accomplished during the sixth year.

2.4: Effect of different sowing methods of wheat:

Noor *et al*., (2022) conducted a research in bed sowing wheat. Results showed that yield was 3.0–4.5 $t \cdot ha^{-1}$ increased in wheat bed sowing. The availability of water at critical stages viz. jointing and anthesis significantly increased effective tillers, total number of tillers, 1000-grain weights and yields. The consumption of soil water was increased at the end stages of growing season and it simultaneous increased the number of grains per spike and test weight of wheat.

Riaz *et al*., (2022) conducted field trial on different methods of sowing and WUE (water use efficiency) in wheat crop which was exposed to water deficit at anthesis. Augmented furrow method of sowing had significantly increased plant height, no. of tillers & test weight. The grain and straw yield was also increased and gave maximum water use efficiency at the anthesis stage. The augmented furrow method of sowing showed the uppermost B:C ratio measurements.

Twizerimana *et al*., (2020) recorded that in winter maximum yield of wheat was noted in wide precise sowing (Wps) method. Three methods had been used i.e dibbling (Db), drilling (Dr), and Wps. The findings showed that Wps, Dr, and Db are largely interchangeable for wheat yield and wheat grain quality attributes. The protein and starch in grain yields were significantly higher at appropriate seed rates of 112.5 kg/ha, 150 kg/ha, and 225 kg/ha respectively.

Hussain *et al.*, (2018) observed that raised beds produced good yield with lower seed rate (75 kg/ha). Results showed that wheat variety having semi erect growth habitat performed well on raised beds than erect growth habitat.

Kamboj *et al*., (2017) noted that wheat raised under zero tillage having spacing of 18cm gave high yield due to more tillering. The wheat grown with bed planter on beds gave longer spike lengths and higher test weight.

Tripathi and Das (2017) noted that bed planting gave better performance of wheat. The results srevealed that bed planting increased production of cereals, pulses and oil seeds than flat sowing.

Ali *et al*., (2016) conduced an experiment on different planting methods. The methods were raised bed, ridging, drilling and broadcasting. It was observed that planting method had great impact on proper crop stand establishment. Results showed that highest drill sowing method had maximum number of wheat plants either growing on beds or flat field. Raised bed planting methods had significantly increased plant height, total number of tillers, number of grains per spike, test weight and grain yield. while other planting methods like ridge sowing and drill sowing were statistically similar in tillers no., no. of spikelets per spike, number of grains per spike and test weight. The bed planting method, ridge sowing method and drill sowing method had significant increase in yield by 24.46%, 20.86% and 17.33% respectively over conventional method of broadcasting. The irrigation water was saved up to 22.47 and 13.26% in raised bed and ridge method. These methods of growing wheat saved water over flat sowing either by drilling or broadcasting. The bed planting wheat showed minimum cost and maximum B:C ratio than conventional method of wheat plantation.

Abdul Majeed *et al*., (2015) noted that the fertilizer use efficiency, reduced the crop logging and increased the grain yield was improved by growing wheat on beds.

Farooq *et al*., (2015) observed that among of three different types of wheat sowing such as raised bed planting, drill sowing and broadcasting. Results revealed that raised bed sowing increased the grain yield and reduced the weed population.

Mollah *et al*., (2015) observed that wheat grown on beds gave better results than conventional methods. The wheat grown on beds (70cm wide) gave a greater number of grains per panicle and increased the panicle length.

Osman *et al*. (2015) concluded that wheat sown with bed planter on raised beds saved more water and nutrients as compare to flat sowing.

Swelem *et al.*, (2015) concluded that sowing of wheat on raised beds (120cm wide) significantly increased the nitrogen content in wheat grain. Application of nitrogen applied at 180 kg per ha significantly increased the yield in bed sowing as compare to other methods.

Noorka *et al*., (2013) concluded that bed planting increased the grain yield by improving the proper aeration, root development and high light penetration in crop canopy.

According to Idnani and Kumar, (2012), the yield contributing factors like test weight and ear head length were significantly higher in three row per bed as compared to traditional methods of sowing of wheat crop.

Jat *et al*. (2011) recorded yield was increased by 16.66% as precision sowing of wheat and raised bed technique and saved the irrigation water up to 50% as compared to traditional methods (flat sowing and flood methods).

Brar and Singh (1997) found the positive effect of sowing wheat in both directions (cross sowing) at close row spacing of 15 cm instead of sowing at a distance of 22.5 (drill sowing) with respect to grain yield and control of weeds.

Zipoli and Grifont (1994) studied the bidirectional reflectance factors (BRFs) in wheat crop & the planting system affected canopy design of plant. It also affected the growth and development of not only wheat but also many other crops.

2.5 Effect of intercropping on *Phalaris minor*:

Mori *et al*., (2022) studied on intercropping and weed control strategies on yield and yield attribues of sorghum during *Rabi* season at south Gujarat where HI became unaffected due to various intercropping and weed management practices. Intercropping of sorghum with Indian bean in the ratio of 2:1 significantly decreased weed count. The DM accumulation of weeds and its count were significantly less at 20 and 40 DAS. The intercropping of sorghum with Indian bean in the ratio 3:2 along with application of pre-emergence pendimethalin 1kg/ha had significantly lower weed competition index.

Minville *et al*., (2022) evaluated intercropping of Vineyard with living mulch. Results revealed that the annual and perennial grass mulches significantly controlled weeds, improve soil structure and increased vine growth and improved fruit quality as compared with weedy vineyard establishment. Living mulch did not affect the fruit quality of vineyard and it reduced the weed species, richness and diversity. The other weed management practices did in intercropping of vineyard along with living mulch improved the soil aggregates and maintained its stability.

Gu *et al*., (2021) reviewed that intercrop had lowest dry matter (58%) than the weaklier weed-suppressive crop species. The intercropping had similar weed biomass than weaklier weed-suppressive crop species. Intercropping had more crop density as compared with sole crops was a key factor in weed suppression. Intercropping was useful approach for suppressing the weeds in annual crop cultivation.

Khatri *et al*., (2019) observed that from different sowing methods SWI (20 cm x 20 cm) had significantly higher number of tillers than line sowing (25 cm) and broadcasting. SWI gave significantly maximum grain yield in both years than line sowing and broadcasting method. SWI method had recorded higher yield attributes and enhanced the wheat productivity. Cost of cultivation had been decreased by controlling the labour requirement.

Koochaki *et al*., (2014) concluded that wheat and canola as row intercropped decreased weed population. Intercropping improved the crop diversity and reduced competition of weed with main crop.

Kour *et al*., (2014) noted that intercropping of maize + potato significantly reduced weed species and weed density. Results revealed that additive treatment value of weed smothering efficiency was higher on comparison with replacement treatment.

Naeem *et al*., (2012) studied weed aspects in intercropping of wheat with canola system. Mixed cropping system like of wheat along with canola reduced the DM accumulation of *Phlaris minor*. The cropping system like intercropping of 4:4 wheat + canola recorded highest land equivalent ratio & suppressed the density of weeds.

Khorramdel *et al*., (2010) studied on effect of intercropping wheat (*Triticum aestivum*) with canola (*Brassica napus*.L) on weed population. The results revealed that intercropping increased the diversity and decreased the weed number, density and population. The minimum value of dry matter were recorded in 4:4 (wheat+ canola) and maximum value was observed in wheat alone.

Wanic *et al*., (2010) studied on role of intercrops on weeds control for spring barley in cereal crop rotation systems. The results revealed that intercrop reduced weed development.

Szumigalski *et al*., (2005) found that intercropping systems of wheat-canola and wheat-canola-pea significantly suppressed weeds as compare to sole component crop. DM accumulation of weeds were recorded less due to application of herbicide.

Al-khatib *et al*., (1999) noted that intercropping of wheat with Brassica species significantly suppressed the weeds, nematodes, insects and diseases. The decomposition product released from brassica istohthiocyanates was the potent inhibitor of weed seed germination and weed seedling growth.

2.6 Grain equivalent yield

Usadadiya *et al*., (2013) observed the intercropping sequence of soyabean-wheat, green gram-wheat and maize-wheat. Results revealed that soybean and green gram had significantly increased grain yield of wheat. Maximum wheat equivalent yield was found in cropping pattern of mung gram-wheat. The (WGE) wheat grain equivalent was recorded maximum net profits with soybean–wheat and gave efficienct land use.

Wasaya *et al*., (2013) recorded that intercropping of wheat along with fenugreek recorded maximum net returns as compared with sole cropping. Results revealed that fenugreek in the ratio of 3:1 wit wheat gave maximum yield advantage (38%) than intercropping of wheat with fenugreek in the ratio of 4:1 (33 %). The minimum returns was observed in the ratio of 1:1 (19%). The intercropping of wheat with fenugreek (3:1) gave maximum net income of Rs. 33647 ha^{-1} and the minimum net income was observed in sole cropping Rs. 24791 ha^{-1}.

Khatun *et al*., (2012) noticed that intercropping reduced the yield as compared with sole crop. Results revealed that intercropping of wheat with three intercrops and four sole crops reduced yield of wheat. Intercropping of wheat along with cowpea produced maximum yield and lowest grain yield was found in intercropping of wheat with linseed. Both the intercropping with wheat gave the higher WEY (wheat equivalent yield) than wheat as sole crop. The other component cops reduced the yield of main crop.

Singh *et al*., (2008) studied on pearl millet, green gram, cluster bean and wheat along with their nutrient management. Higher grain wheat yield was found in clusterbean and green gram grew as a preceding crops. Better uptake of N and P was found in green gram and clusterbean whereas minimum uptake was found in pearl millet. Maximum net returns and wheat equivalent yield was found in green gram. The maximum WGEY was found in the application of FYM along with 50% of RDF. The cost benefit ratio was found in green gram having application of FYM+50%RDF+biofertilizer.

Kharub *et al*., (2003) noticed the cropping sequence of rice-potato-vegetable pea-wheat. The maximum wheat-equivalent yield was found in potato followed by vegetable pea. These systems increased the O.C, available nitrogen & available phosphorous by 8.9%, 17.1%, 8.3% and 19% as compared with traditional cropping system (rice-wheat).

Khan *et al*., (2000) studied on intercropping of wheat with alternate 2, 3 or 4 row strips of safflower gave the highest head diameter (2.61 cm) and number of grains per head (40.40) in safflower intercropped with wheat in alternate 3 row strips. Safflower 1000-grain weight was highest in safflower intercropped with wheat in alternate 2 row strips. The intercropping regimes gave greater wheat grain equivalent yield than wheat monoculture

Nayital *et al*., (1991) observed that wheat grown with brown sarson (*Brassica compestris var*. *sarson*) in 4:1 row ratio significantly decreased the weed density and increased grain yield. Intercropping system gave maximum grain equivalent yield.

2.7 Quality parameters of wheat

Asthir *et al*., (2017) studied on different doses of N application. It had been found that control nitrogen gave lower true protein whereas split doses of N application gave higher true protein content. From the different types (fraction) of proteins, the fraction of albumin type was increasedby increasing in seed rate whereas other protein fractions like prolamin and glutenin was unaffected with different seed rates.

Xue *et al*., (2016) studied on reproductive stages heading and anthesis. The application nitrogen during late stages made high bread-making quality wheat. Grain protein concentration had no effect with split N application. The glutenin fraction and baking quality of wheat was enchanced by split N application.

Mohammed *et al*., (2013) noticed that protein content of wheat was significantly increased with the application of more dose of nitrogen fertilizer and it also enhanced yield of wheat crop. In split doses of nitrogen application, the wheat grain yield and protein was significantly higher. It also increased NUE.

Gao *et al*., (2012) found that supply nitrogen in form of urea enchanced the protein content in wheat grain. Results showed Fe & Zn in grain was not affected by nitrogen fertilization. The trait was not consistently affected by any source and its time of nitrogen fertilizer. High protein concentration was affected by did split of N fertilization.

Abedi *et al*., (2011) reported that different nitrogen rates and nitrogen timing significantly influence the grain yield, yield components, grain quality and protein content. Seed gluten content was not effected by different N rates.

Subedi *et al*., (2007) noted that the planting date and N had significant effects on grain yield and grain protein content (GPC) of wheat crop. It showed yield of wheat grains was decreased by 15 to 45% due to delayed beyond mid-May. It was significantly increased the GPC by 6 to 17%. Split doses of N fertilizer significantly increased the grain yield but had no effect when applied as top dress or foliar spray.

Garrido-Lestache *et al*., (2005) observed that kernel count was significantly increased by different N rates. Grain yield and quality indices were not affected by the timing and splitting of N fertilization. By the foliar application of nitrogen fertilizer at critical stages like emergence of ear in wheat significantly enhanced the protein, quality content, count of grains & ash content of seeds. Quality indices like ash content was not affected by oil and also not affected by application of S on leaves at emergence of ear stage.

Garrido *et al.*, (2004) reported that alveogram index values was significantly increased by different nitrogen rates. Result revealed that dough balance was improved by nitrogen rates whereas gluten index had no effect of different N rates. Grain protein and alveogram index was affected by different rates of N application at ear emergence.

Lloveras *et al.*, (2001) noted that wheat quality was enchamced by different rates of nitrogeneous fertilizers. After the harvest of crop, NO_3 was found as a residual and N fertilization increased its concentration. Protein content in grain was significantly increased by N fertilization. it also affect the bread quality parameters. After the harvest, the NO_3 content in soil was increased.

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Chapter 3 MATERIAL AND METHODS

The experiment entitled **"Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice-based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** was conducted during the *Rabi* season of 2020-2021 and repeated in 2021-2022, at Research Farm of Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara Punjab. The details of the material used and methodology adopted in these investigations are discussed in this chapter. This chapter consists of a brief description of the location of the experiment, climate with meteorological data, soil characteristics, experimental design, land preparations, layout and observations on different agronomic practices under the following sub-headings.

3.1 Experimental site description

3.1.1. Experimental site

The experiment had been conducted at the research farm of Lovely Professional University during 2020-2021 and 2021-2022. The farm is situated at 31^{0}22'31.81'' North latitude and 75^{0}23'03.02" East longitude with 252 m average elevation from above mean sea level. It falls under the sub-tropical region in the central plains of agro-climatic zone.

3.1.2. Climatic and weather condition

This experimental site falls under the subtropics regions, remains cool in winter and hot in summer, maximum rainfall in the month of July, August, and September due to the South-West monsoon. The temperature never goes below zero degree in December and January which remains extremely cold. The highest temperature was recorded as nearly 46ºC in months of May, and June. Monsoon rains start in the first fortnight of July and continues to the end of September if the South-West monsoon is not delayed. Frequent rainfall occurs in the month of July and August. Average different weather variable (temperature maximum, temperature minimum, and rainfall) data were recorded at different crop growth stages. The optimum temperature for wheat crop is 20-25°C. It tolerates up to a maximum temperature of 35°C. Normally wheat crop for germination and initial growth requires a cool climate and it requires high temperature during latter stages of crop growth and at reproductive phase.

Table 3.1: Monthly weather data during both the cropping years

Month	Maximum temperature (ºC)			Minimum temperature(ºC)			Relative humidity (%)			Rainfall (mm)		
Year	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
October	34.23	33.23	---	21.81	22.45	---	35.13	49.07	----	0.97	0.11	--
November	25.87	24.36	---	15.82	14.23	---	55.37	50.37	-----	0.07	0.01	--
December	16.65	19.47	---	11.10	9.61	----	57.69	59.48	----	0.0	0.02	--
Janauary	--	13.52	15.97	--	8.39	10.29	--	72.19	69.36	--	3.47	1.15
Febuarary	--	22.93	16.29	--	12.21	9.04	--	65.98	65.59	--	0.59	0.61
March	--	29.77	26.42	--	17.13	17.84	--	50.04	48.92	--	0.14	0.03
April	--	31.17	38.60	--	16.4	27.67	--	35.64	36.68	--	0.92	0.13
May	--	38.06	39.84	--	25.58	30.32	--	32.31	32.55	--	1.68	0.25

3.1.3 Soil sample collection

Samples collected randomly before conducting the investigation. After scraping surface, v-shaped cut was made. The cut was 6 inches deep and thickness of slice was 1-inch thick from one side of cut. In the same way, 10 to 12 samples were collected in zigzag direction from field. Finally, about 500 g soils were collected after mixing the soil samples uniformly. The sample was used for checking different properties of soil. Again samples were collected at harvesting time and then analyzed. Sandy loam was the soil experimental site. Soil was well fertile & well tilth soil which is under rice-wheat system having good drainage and rich in nutrients. The status of field had normal pH (7.9) with medium level of O.C (0.58%), available N (145 kg per ha) and medium level of P_2O_5 (12.2 kg per ha) and K_2O (178.4 kg per ha).

3.1.4 The physical and chemical properties of experimental field

Region belongs to alluvial and sandy loam soil class. Sample of soil were collected before the conduct of experiment from the research area. Randomly from five spots soil samples were was collected at 15cm depth and after mixing the soil and examined for the following chemical properties (Table 3.1.1).

Table 3.2: Soil properties of experimental field

Sr. no.	Particulars	Values (0-30 cm depth)	Method employed
Physical properties			
1	Coarse sand%	62%	International pipette method
2	Silt%	8%	
3	Clay%	29%	
Chemical properties			

1	pH	7.9	Beckman's glass electrode meter
2	Electrical conductivity (ds m^{-1})	0.21	Solu-bridge Conductivity meter
3	O.C (%)	0.58	Rapid Titration Method (Walkley and Black 1934)
Available Nutrient Status			
1	Available Nitrogen (kg ha^{-1})	145 (low)	Kjeldahl method (Johan Kjedahl, 1883)
2	Available Phosphorous (kg ha^{-1})	12.2 (medium)	Olsen method (Olsen, 1954)
3	Available Potassium (kg ha^{-1})	178.4 (medium)	Flame photometry (Jackson, 1967)

3.2 Details of procedure are given below:

3.2.1 Triangle method for soil textural class

U.S. soil texture triangle method (soil survey, 1998) was used for the determination of soil textural class.

3.2.2 Particle distribution (percentage)

Soil texture was estimated by the international pipette method (Piper, 1996); take 50g of soil and sieved in 2mm then put it in a conical flask of 500 ml. Now add 100 ml dispersion solution into it. To make a homogeneous solution put the flask on a shaking machine for half an hour. The solution was transferred into a 1000 ml measuring cylinder and make solution of 1000 ml. The solution was shaken for 30 sec as per international approved system. 50 ml pipette was used at 30cm depth for second pipetting. It was taken and transferred it into 60 ml china dish. Clay particles was present in the solution. Now the rest of solution was transferred into a 1 litre measuring cylinder and sieved from 0.02 mm sieve, sand particles were obtained. Pipette solution was taken in three dishes and kept it overnight at the temperature of 105° C. By cooling the dishes in desiccators, weigh it quickly. By subtracting weight of silt, sand, clay and coarse particle from 100, the fine particles was obtained.

3.2.3 pH: Transfer 10 g of soil in 100 ml beaker. Distilled water was added 25 ml in the beaker. Stir the sample for a few minutes, wait to settle the sand particle at the bottom. Dip the electrode in solution and to find out the alkaline nature of soil.

3.2.4 Electrical conductivity

For the determination of electrical conductivity (ds/m), water suspension method of Jackson (1973) was used. In 100 ml container add 25 g of dried soil and 50 ml distilled water. Mixed the sample for 30 min for making homogeneous suspension and left it for another 30 min without any disturbance. Insert the conductivity cell in to the solution and record the EC value.

3.2.5 Organic carbon

For the estimation of O.C, Rapid titration method of Walkely and Black (1934) was used. Take 2 g of soil sample and transferred it into 250 ml of conical flask. 1N potassium dichromate was added (10 ml) with 20 ml of concentrated H_2SO_4. For one minute, solution was shaken and then rest it about 30 min. Distilled water of 200 ml had been added along with 10 ml of orthophosphoric acid. Then added 4 drops of diphenylamine indicator which gave violet colour. The upper solution was titrated with ammonium ferrous sulphate and violet colour was changed into bright green colour.

3. 2.6 Available Nitrogen

Alkaline permanganate method was used for estimating the available N fron the soil. Take 5 g of soil and put it into Kjeldhal distillation assembly. Add 0.32% potassium permanganate in the quantity of 25 ml into the distillation assembly. Now add N/50 concentrated sulphuric acid of 10 ml with 2 drops of red methyl indicator. The delivery tube was placed in the content of conical flask. Then distillation started, after the distillation 30 ml of content was collected in conical flask and titrated with N/50 NaOH. When the colour changed from pink to yellow, the end product was obtained.

3.2.7 Available Phosphorous

For the estimation of phosphorous, Olsen method (1958) was used. In the beaker take 1g of soil and add 0.5 sodium bicarbonate solution (20ml) then add pinch of Darco-G and with the help of electric shaker, shake it for half an hour then filtered it with the help of Whatman No.1 filter paper. In the same way, the blank solution was get ready. Take 5 ml of solution from the filtered solution in a container and add 5 ml of sulfuric acid into it. Then shake the solution until the CO_2 was evaluated. Take 4 ml of ascorbic acid in another container and make volume by adding distilled water into it. The flask content was mixed and blue colour was developed and measured by using a calorimeter at 760 nm wavelength.

3.2.8 Available Potassium

For the estimation of potassium, 1N Ammonium acetate method was used. Take 5 g of dried soil and 25 ml of ammonium acetate into 150 ml of conical flask. With the help of mechanical shaker, shake the sample for 5 min and then filtered it through Whatsman No.1. filter paper. In the distilled water add 5ml of soil extract. With the help of flame photometer, diluted extract was atomized and noted down the reading of K.

3.3 History of cropping site

At the experiment site, rice –wheat rotation was followed for several years as shown in Table 3.2.

Table 3.3 Cropping history of experimental field

Year	Crop rotation
2017-18	Rice-Wheat
2018-19	Rice-Wheat
2019-20	Rice-Wheat
2020-21	Rice-Experimental crop
2021-22	Rice-Experimental crop

3.4 Details of experiment design

Randomized Block Design was adopted during 2020-21 and 2021-22. Both experiments contained 14 treatments and 4 replications.

Annova Table

Source of Variance	**d.f**
Replications	3
Treatments	13
Error	39
Total	55

3.4.1 Experiment 1: Role of different *Rabi* crops for controlling *Phalaris minor* Retz. in comparison to wheat (*Triticum aestivum* L.)

Experimental design: Randomized Block Design (RBD)

Treatment Details:

T1 - Rice - Wheat, Weed free

T2 - Rice - Wheat, Weedy

T3 - Rice - Gobhi Sarson (Seeded)

T4 - Rice - Gobhi Sarson (Transplanted)

T5 - Rice - African Sarson (Seeded)

T6 - Rice - African Sarson (Transplanted)

T7 - Rice - Raya (Seeded)

T8 - Rice - Barley

T9 - Rice - Berseem

T10 - Rice - Lentil

T11 - Rice - Potato – Radish (for seed)

T12 - Rice – Potato- Carrot (for seed)

T13- Rice- Oats (fodder and seed)

T14-Rice- Fennel

3.4.2 Experiment 2: Smothering potential of different intercrops on *Phalaris minor* Retz. in bed planting technology of wheat

Experimental design: Randomized Block Design (RBD)

Treatment Details:

T1 - Bed sowing, Weed free

T2 - Bed sowing, Weedy

T3 - Bed sowing, intercropping of Gobhi Sarson (T), Weed free

T4 - Bed sowing, intercropping of Gobhi Sarson (T), Weedy

T5 - Bed sowing, intercropping of African Sarson (T), Weed free

T6 - Bed sowing, intercropping of African Sarson (T), Weedy

T7- Bed sowing, intercropping of Lentil, Weed free

T8 - Bed sowing, intercropping of Lentil, Weedy

T9 - Bed sowing, intercropping of Fenugreek, Weed free

T10 - Bed sowing, intercropping of Fenugreek, Weedy

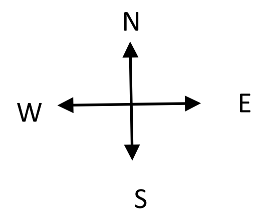
T11 - Bed sowing, intercropping of Fennel, Weed free

T12 - Bed sowing, intercropping of Fennel, Weedy

T13 - Bed sowing, intercropping of Dill seed (soya), Weed free

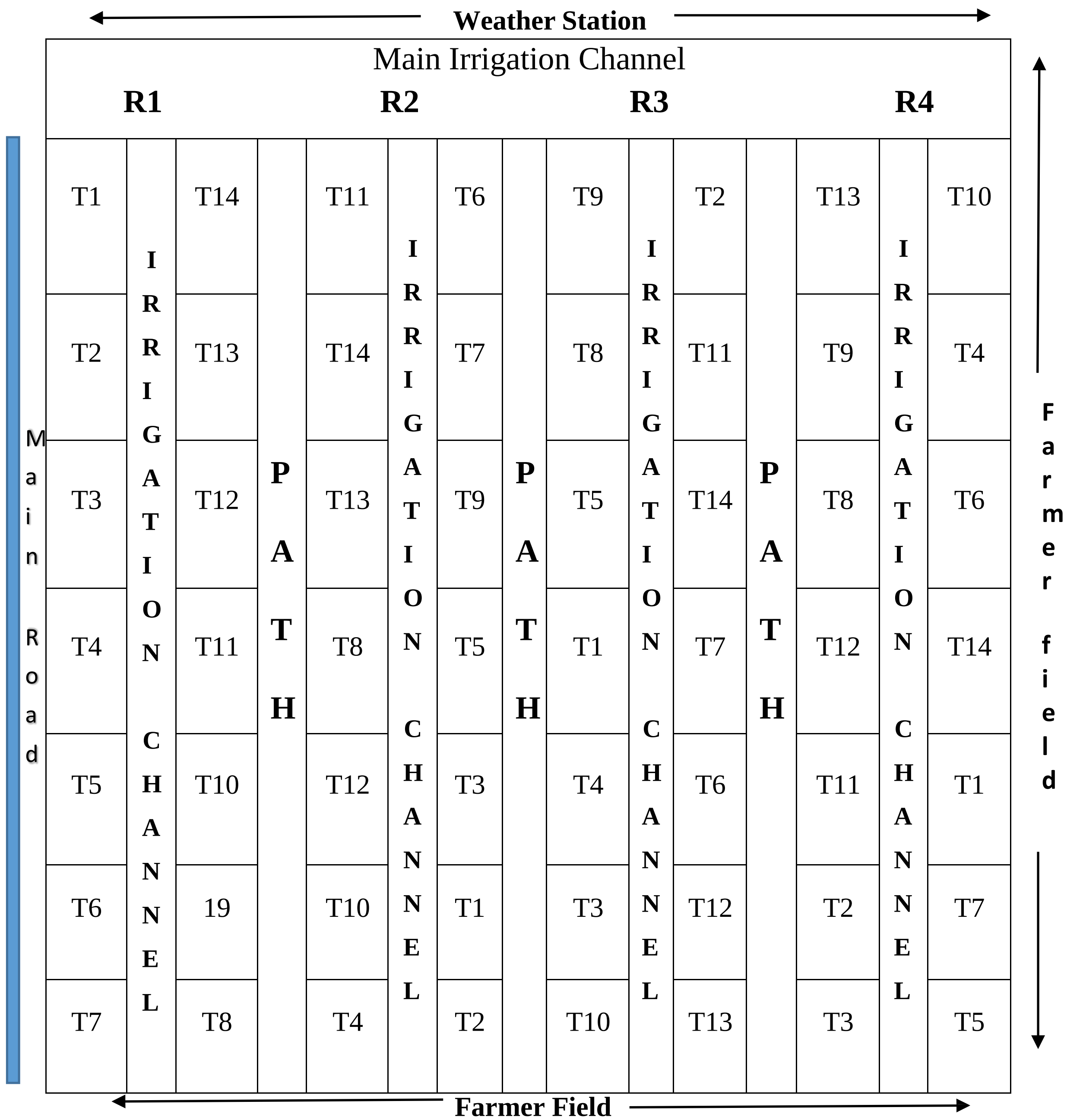
T14 - Bed sowing, intercropping of Dill seed (soya), Weedy

Note: T-Stands for transplanted crop



Layout

Layout of experiment 1



N
W E
S

Layout of experiment 2

← **Kacha Road** →

Main Irrigation Channel

Main Road (west side) | Farmer field (east side)

R1		R1		R2		R2		R3		R3		R4		R4
T1	IRRIGATION CHANNEL	T14	PATH	T11	IRRIGATION CHANNEL	T6	PATH	T9	IRRIGATION CHANNEL	T2	PATH	T13	IRRIGATION CHANNEL	T10
T2		T13		T14		T7		T8		T11		T9		T4
T3		T12		T13		T9		T5		T14		T8		T6
T4		T11		T8		T5		T1		T7		T12		T14
T5		T10		T12		T3		T4		T6		T11		T1
T6		19		T10		T1		T3		T12		T2		T7
T7		T8		T4		T2		T10		T13		T3		T5

← **Weather station** →

3.5 Details of crops in the experiments:

Different crops grown in both experiments and their details are shown in Table 3.3:

3.5.1 Wheat: Unnat PBW 343 which was recommended variety used in both the experiments. This variety of wheat was released in 2017 at PAU and it is an better-quality variety of PBW 343. It has the average height about 100 cm and takes 155 days to attain maturity. This variety has average grain yield of about 58.0 q/ha. This variety of wheat is completely resistant to brown rust where as moderately resistant to yellow rust and susceptible to loose smut.

3.5.1.1 Land preparation: Rauni which is the pre-sowing water was applied. The experimental land was ploughed three times with disk harrow once but twice with cultivator followed by planking to ensure good germination during both years.

3.5.1.2 Method of sowing and sowing time: The wheat was sown on 2 November 2020 and in second year it was sown on 4 November 2021. This variety has 22.5 cm row to row spacing.

3.5.1.3 Fertilizer application: The application of phosphorous and potassium was done in single split (basal application) at sowing time. The application of nitrogen was done in 2 split doses before the application of first and second irrigation. Wheat requires 125 kg per ha N and 62.5 kg per ha P_2O_5.

3.5.1.4 Irrigation: The post sowing irrigation which was the second one applied after 28 DAS (days after sowing) of wheat crop and succeeding three irrigations were given as per crop requirement for its proper growth and development during both years.

3.5.1.5 Plant protection: For control of aphid, one spray of thiamethoxam 25 WG @ 50 g/ha was applied. Tebuconazole 25EC 500 ml/ha in 500 liter water were also applied in the end of February which resulted in an effective control against yellow rust.

3.5.1.6 Harvesting and threshing of wheat: The harvesting of wheat becomes necessary when the grain becomes hard and its straw become dry and brittle. Make the small size bundles of harvested crop and then collected. The collected bundles was left in field for complete drying by sun at least for one week. These wheat bundles were weighed and after that thrashing was done with tractor operated thrasher. Collect all the grains and then clean them. After cleaning it was expressed in q/ha.

Table 3.4 Details of sowing of different crops in experiment 1 and experiment 2

Name of crops	Variety	Spacing	Sowing time (2020-21)	Sowing time (2021-22)	Seed rate/ ha	Fertilizer kg/ha
Wheat	Unnat PBW343	22.5cm	2 Nov	4 Nov	100 kg	125 kg N, 62.5 kg P_2O_5
Raya	RCH 1	30cmx15cm	22 Oct	25 Oct	3.75 Kg	100 kg N, 30 kg P_2O_5
Gobhi Sarson	PGSH 1707	45cmx15cm	22 Oct	25 Oct	3.75 Kg	100 kg N, 30 kg P_2O_5
African Sarson	PC 6	30cmx15cm	22 Oct	25 Oct	3.75 kg	100 kg N, 30 kg P_2O_5
Barseem	BL 42	Broadcast	22 Oct	25 Oct	25kg	25 kg N, 75kg P_2O_5
Oats	OL-13	22.5cm	22 Oct	25 Oct	62.5 kg	37.5 kg N, 20kg P_2O_5
Dill seed	Local	45cm	22 Oct	25 Oct	5kg	87.5kg N
Fennel	Local	45cm	22 Oct	25 Oct	10 kg	50kg N
Barley	PL 891	22.5cm	2 Nov	4 Nov	125 kg	62.5 Kg N, 30kg P_2O_5
Lentil	LL 931	22.5cm	22 Oct	25 Oct	30kg	12.5kg N, 20 kg P_2O_5
Potato	Kufri Pukhraj	60x20cm	22 Oct	25 Oct	37.5q	187.5 kg N, 62.5 kg P_2O_5 and 25 kg K_2O
Fennugreek	Local	22.5	2 Nov	4 Nov	25kg	12.5 Kg N,20 Kg P_2O_5
Carrot	Local	45cm	2 Feb	3 Feb	12.5kg	62.5kg N, 30 kg P_2O_5 and 75 kg K_2O
Radish	Local	45cm	2 Feb	3 Feb	12.5 kg	62.5kg N, 30 kg P_2O_5

3.5.2 Mustard: (a) **Raya**: RCH 1 of hybrid Raya was used. It was released in 2019. It is recommended for general cultivation having yellow seeded and medium tall variety.

b) **Gobhi sarson**: PGSH 1707 canola hybrid of gobhi sarson was used. This hybrid is resistant to white rust and has 41% oil content.

c) **African sarson**: PC 6 was the variety of African sarson mustard that was used (2016). PC6 is the first African sarson variety released by PAU. This variety is mainly for cultivation under appropriate sowing irrigated conditions. This is resistant to white rust variety and also tolerate the mustard aphid and Alternaria blight disease.

3.5.2.1 Seed rate: About 3.75 kg/ha seed rate was used.

3.5.2.2 Method of sowing and sowing time: The Mustard had sown in line with the help of seed drill. The Gobhi sarson was sowing at 45x15cm whereas African sarson Raya were sowing at 30cm. Nursery of Gobhi and African sarson had been transplanted after 30DAS. In the second trial, the Gobhi sarson and African sarson were transplanted in between two beds of wheat. In the first year, the Gobhi sarson, African sarson and Raya was sown on 22 October 2020 and 25 October 2021 in the second year.

3.5.2.3 Fertilizer application: The Mustard requires 100 Kg N/ha and 30Kg P_2O_5/ha. Urea is used as source of nitrogen in split doses whereas DAP is used for meeting phosphorus requirement.

3.5.2.4 Irrigation: The first irrigation was applied at 30DAS. The pre recommended irrigations were given to African sarson, Raya subsequently.

3.5.2.5 Harvesting and threshing: Gobhi, African and Raya sarson were harvested when pods turned yellow. The harvested crop was stacked for 10 days and then thrashed manually.

3.5.3 Barseem: BL 42 is the variety of Barseem was sown in the experiment. This variety of barseem produced more number of tillers and was stem rot tolerate.

3.5.3.1 Seed rate: It was used at the seed rate of 25 kg/ha.

3.5.3.2 Method of sowing and sowing time: The land was prepared with disc plough and cultivator. The seeds of Barseem were broadcast in the standing water. In the first year, the Barseem was sown on 22 October 2020 and 25 October 2021 in the second year.

3.5.3.3 Fertilizer application: Barseem requires 25 Kg N/ha & 75 kg P_2O_5/ha. Nitrogen was applied in split doses in the urea form.

3.5.3.4 Irrigation: Subsequent irrigations were given as per crop requirement.

3.5.3.5 Harvesting: After 30 DAS, the first cutting of barseem which was mixed with raya was taken and four cuttings were taken later on.

3.5.4 Oats: OL-13 oats variety was grown in this experiment. This was a single cut variety. It has tall plants having profuse tillering and leafy growth. It is a dual purpose variety.

3.5.4.1 Seed rate: 62.5 kg ha^{-1} seed rate was applied.

3.5.4.2 Method of sowing and sowing time: The oats were sown in the line with spacing of 22.5 cm.

3.5.4.3 Fertilizer Application: Oats required the 37.5 Kg N ha^{-1} & 20 Kg P_2O_5 ha^{-1} for their proper growth and development. The Nitrogen was applied in split doses. After the first cutting, the second dose of nitrogen was applied.

3.5.4.4 Harvesting: First cutting of oats was taken at 45 DAS and then seeds were taken when pods turned yellow. Grains were cleaned and weighed and expressed as grain yield (q/ha).

3.5.5 Carrot: The local variety was used.

3.5.5.1 Seed rate: 12.5 kg ha^{-1} seed rate was applied.

3.5.5.2 Method of sowing and sowing time: The carrot was sown on the ridges at 45cm and 7.5 cm plant to plant apart. After the harvesting of potato, it was transplanted by taking 2-3 inches top portion cuttings into the field. It was transplanted on 2 Feb 2021 in the 1^{st} year & on 3 Feb 2022 in the 2^{nd} year was transplanted at spacing of 45 cm x 7.5 cm.

3.5.5.3 Fertilizer application: Carrot required the 62.5 Kg N ha^{-1} and 30 Kg P_2O_5 ha^{-1} and 75 kg K_2O ha^{-1} for its growth and development.

3.5.5.4 Harvesting: Harvesting was done when the fruit (umbels) changing its colour from green colour to light yellow one. After making bundles and sun drying, it was threshed manually.

3.5.6 Radish: The local variety was used.

3.5.6.1 Seed rate: It was used at the 12.5 kg ha^{-1} seed rate.

3.5.6.2 Method of sowing and sowing time: The radish was sown on the ridges at 45cm apart and 7.5 cm plant to plant apart. After the harvesting of potato, 2-3 inches radish cuttings (tops) were transplanted in the field with row to row 45 cm and plant to plant 7.5 cm spacing. It was transplanted on 2 Feb 2021 in the 1st & on 3rd Feb 2022 in the second year.

3.5.6.3 Fertilizer application: Radish required the 62.5.5 Kg N ha^{-1} and 30 Kg P ha^{-1}.

3.5.6.4 Harvesting: Harvesting was done when the colour of pods get turn from green to light yellow brown. After making bundles and sun drying, it was threshed manually.

3.5.7 Fennel: The local variety of fennel was used.

3.5.7.1 Method of sowing and sowing time: The seed was sown at 3-4 cm deep with the help of hand drill by kera method with the spacing of rows 45 cm apart. It was sown on 22 October 2020 in 1st year and in 2nd year it was sown on 24 October 2021.

3.5.7.2 Seed rate: the seed rate of 10 kg/ha was applied.

3.5.7.3 Fertilizer application: It requires 50 kg/ha nitrogen. So, 112.5 kg/ha urea was applied in 3 splits.

3.5.7.4 Harvesting: Harvesting was done when the colour of umbels become changed from green to light yellow. After making bundles and sun drying, it was threshed manually.

3.5.8 Barley: PL 891 was used for sowing. This variety of barley has two hulless rows. It is matured in 144 days having 102cm height and have 4% beta glucan with the protein content of 12%. The average grain yield of this variety is 46 q/ha.

3.5.8.1 Seed rate: It was used at the 87.5 kg/ha seed rate.

3.5.8.2 Method of sowing and sowing time: The barley was sown on 2 November 2020 and in second year it sowed on 4 November 2021. It has the spacing of 22.5 cm which is recommended for conventional sowing of barley.

3.5.8.3 Fertilizer application: It required the 62.5 Kg N per ha and 30 Kg P_2O_5 per ha. The N was applied in split doses whereas phosphorous was applied at the time of sowing as a basal dose.

3.5.8.4 Harvesting and threshing: The barley was harvested when the grains become hard and the straw becomes dry and brittle. The crop after harvesting was collected in small bundles whereas for sun drying purposes, the bundles were left in the field for 1 week.

3.5.9 Potato: Kufri Pukhraj is an early bulking potato variety. The plants were vigorous, tall and erect. It was susceptible to late blight & tubers were oval, large uniform and white with fleet eyes. It had 17-18% dry matter content and yield of 325 q/ha in 70-90 days.

3.5.9.1 Seed rate: 37.5 q/ha of seed rate was applied.

3.5.9.2 Method of sowing and sowing time: Ridges was made at 60 cm apart and keep tuber to tuber distance was 20 cm. It was sown on 22 October 2020 in the first year & it was sown on 24 October 2021 in the second year.

3.5.9.3 Fertilizer application: It required the 187.5 KgN/ha, 62.5 Kg P_2O_5/ha and 62.5 Kg K_2O/ha. The whole dose of P & K was given with half Nitrogen during time of sowing and rest of Nitrogen during the earthing-up time.

3.5.9.4 Irrigation: After sowing of potato, it is necessary to provide the first irrigation & successive irrigations were given as per crop requirement.

3.5.9.5 Earthing up: In case of potato crop, earthing up was done with spade 40 days after sowing.

3.5.9.6 Harvesting: Digging of potatoes was done 90 days after sowing.

3.5.10 Lentil: LL 931 variety was used in both experiments. Its erect short plants with profuse branching. Each branch had bearded more no. of pods. The flowers are pink with dark green leaves. It also had non-pigmented green pods with rudimentary tendrils.

3.5.10.1 Seed rate: it requires 30kg/ha seed rate.

3.5.10.2 Method of sowing and sowing time: with the help of seed drill place seed at 3-4 cm deep in rows 22.5 cm apart. It sowed on 22 October 2020 in the 1st year and in the 2nd year it was sown on 24 October 2021.

3.5.10.3 Fertilizer application: Lentil required 12.5kgN per ha and it required P as 20 Kg per ha.

3.5.10.4 Harvesting: It was done when lentil become ready at that time their leaves starts fall down, whereas stem or pod colour change to brown or in straw colour. It was cut and made bundles. After sun drying, it was threshed manually.

3.6 Details of crops in second experiment

3.6.1 Wheat: In this experiment**,** the wheat variety Unnat PBW 343 was sown. It has 100cm height and takes 155 days for maturity. The average grain yield is 58.0 q/ha.

3.6.1.1 Land Preparation: The experimental site was cultivated thrice, one with disc harrow and two with cultivator. After that planking was done with the help of planker. The beds have been prepared with the help of tractor. The size of bed was 67.5 cm with 37.5 cm bed top and 30 cm furrow.

3.6.1.2 Method of sowing and sowing time: At the upper portion of the bed, there was two lines of wheat which were sown. In between the two beds, the intercrops was sown. In this experiment, wheat was sown on 2 November 2020 and in the next year it was sown on 4 November.

3.6.1.3 Fertilizer application: Wheat require 125 Kg N per ha & 62.5 kgP_2O_5 per ha. The N was given as Urea form. The urea was supplied in two split doses i.e.half of urea at sowing time and half after first irrigation. The phosphorous was applied as a basal dose at the time of sowing.

3.6.1.4 Harvesting and threshing: When the grains become hard and the straw becomes dry and brittle. The crop after harvesting was collected in small bundles. For sun drying purpose it was left for one week in the field. After that threshing was done.

3.6.2 Mustard:

3.6.2.1 Gobhi sarson: PGSH 1707 of gobhi sarson was used which is the canola quality hybrid free from white rust. It has tall height with profuse siliquae. It was sown in the last week of October.

3.6.2.2 African sarson: PC 6, the variety of African sarson mustard was used (2016). This Brassica variety was developed by PAU. It is sown in well-timed irrigated condition states. There details are as follow.

Seed rate: It was used at the seed rate of 3.75 kg/ha.

Method of sowing and sowing time: Mustard was transplanted in between the two beds of wheat. Seedlings of 30 days old were transplanted on 2 November 2020 in the 1st year and in the 2nd year it was transplanted on 4 November 2021.

Fertilizer application: The Mustard requires 100 Kg N per ha and 30Kg P_2O_5 per ha. The Urea is given as N and P is given in the form of Diammonium phosphate. The urea was supplied in split doses i.e., half at sowing and half about one month of sowing.

Harvesting and threshing: Gobhi, African sarson were harvested when pods turned yellow. The harvested crop was stacked for 10 days and then thrashed manually.

3.6.3 Lentil: LL 931 variety had been used in both experiments. Its plants bear more pod numbers & are erect, short with profuse branching.

3.6.3.1 Method of sowing and sowing time: The lentil was intercropped with wheat crop. It was sown in between the two beds of wheat. Lentil sowed on 2nd November 2020 in 1st year and 4th November 2021 in the 2nd year.

3.6.3.2 Fertilizer application: Lentil required 12.5 KgN/ha and 20 KgP_2O_5/ha whose full phosphorous and half nitrogen was applied at sowing and remaining nitrogen at one month of sowing.

3.6.3.3 Harvesting: The harvesting time of crop is starting drop down the leaves and spods changing its colour to brown. It was cut and made bundles. After sun drying, it was threshed manually.

3.6.4 Fennel: The local variety of fennel were used.

3.6.4.1 Method of sowing and sowing time: The seeds were sown 3-4 cm deep by using hand seed drill in between wheat's two beds. In the first year fennel was sown on 2^{nd} November 2020 whereas it was sown on 4^{th} November 2021 during second year.

3.6.4.2 Seed rate: It requires 10 kg/ha seed rate.

3.6.4.3 Fertilizer application: It requires nitrogen 50 kg/ha. 112.5 kg/ha urea had been applied in 3 splits.

3.6.4.4 Harvesting: Harvesting was done when the fruit (umbel) turns from green colour to light yellow. After making bundles and sun drying, it was threshed manually.

3.6.5 Fenugreek: The local variety of fenugreek was used.

3.6. 5.1 Seed rate: it had 30 kg/ha seed rate.

3.6.5.2 Method of sowing and sowing time: The seeds were sown 3-4 cm deep by seed drill in between two beds of wheat. It was sown on 2^{nd} November 2021 in the 1^{st} year and it was sown on 4^{th} November 2020 in the second year.

3.6.5.3 Fertilizer application: It requires the nitrogen of 12.5 kg N /ha and 20kg P_2O_5/ha. Nitrogen was applied in 3 splits.

3.6.5.4 Harvesting: Harvesting was done when colour of pods turns yellow to light brown. After making bundles and sun drying, it was threshed manually.

3.6.6 Dil seed: The local variety was used.

3.6.6.1 Seed rate: It requires the seed rate of 5 kg/ha. It had been sown with the seed drill manually at depth of 3-4 cm.

3.6.6.2 Method of sowing and sowing time: It was sown 3-4 cm deep by kera method in between two beds of wheat. It was sown on 2 Nov 2021 in the 1st year and during the 2nd year it was sown on 24 Nov 2020.

3.6.6.3 Fertilizer application: It requires the nitrogen of 87.5 kg/ha. 187.5 kg/ha urea had been applied in 3 splits.

3.6.6.4 Harvesting: Harvesting was done when the umbel gets green to light yellow in colour. After making bundles and sun drying, it was threshed manually.

3.7 Observations recorded

3.7.1 Growth parameter:

3.7.1.1 Plant height: Plant height (cm) for each plot was recorded by taking observations from ten randomly tagged plants and average of these observations was calculated at a regular interval of 30, 60, and 90 DAS and at harvest.

3.7.1.2 Tillers number: The number of tillers in wheat and barley were observed from 1 meter row length from each plot at 30, 60, 90 DAS intervals and effective tillers were counted at harvest.

3.7.1.3 Dry matter accumulation (q/ha): DM of crop was calculated from each plot at 30, 60, 90 DAS interval from an area of running one meter per sq.ft. and then converted to q/ha.

3.7.2 Yield parameters (at harvest):

3.7.2.1 Number of grains per ear:

From each plot of wheat and barley number of grains per ear were counted at random by selecting five plants.

3.7.2.2 Length of ear (cm):

The ear length was measured with scale by selecting five ears randomly and then an average value was calculated.

3.7.2.3 Grains per ear: After randomly selecting five ear, numbers of grains were recorded simply by counting.

3.7.2.4 Number of pods per plant: Numbers of pods of mustard, radish and lentil were counted at random by selecting five plants from each plot.

3.7.2.5 1000 grain weight (g): test weight was recorded by counting 1000 seed lot and then weight by using weighing balance.

3.6.2.6 Grain yield (q/ha):

Each experimental plot was harvested from two square meter and threshed separately and after that, yield was recorded & changed into quintal ha per hectare.

3.6.2.7 Straw yield (q/ha):

Separate grains from each plot after threshing, then the weight of grains are subtracting from biological yield to determined straw yield.

3.6.2.8 Biological yield (q/ha):

Biological yield was recorded when plant reach to harvesting maturity. Crop was harvested and made bundles of it after that plot wise they were weighed.

3.6.2.9 Harvest index (HI):

HI was determined by dividing economic yield with total biological yield and after that the value was multiplied by 100 to express HI in percentage.

$$\text{Harvest index (\% age)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.8 Studies on *Phalaris minor*

3.8.1 *Phalaris minor* count: *Phalaris minor* count was taken from two quadrates of 30cmx30cm per plot and converted to per square meter basis at 30,60, 90 DAS and at harvest.

3.8.2 *Phalaris minor* dry matter: Dry matter of *Phalaris minor* was collected from two quadrates of 30 cm x 30 cm per plot at 30, 60, 90 DAS and at harvest which was converted to q/ha after oven drying for presentation.

3.9 Statistical analysis

The observed data were recorded & analyzed by following the guidelines of OPSTAT (developed O.P. Sheoran) by at level of 95 % significance to check the influence of different variables.

Annova Table

Source of Variance	**d.f**
Replications	3
Treatments	13
Error	39
Total	55

Plot Preparation

Sowing of different *Rabi* crops

Phalaris minor in fennel

Phalaris minor in Berseen

Phalaris minor in Barley

Overview of different *Rabi* crops for controlling *Phalaris minor* in comparison to wheat (*Triticum aestivum* L.)

Land Preparation

Preparation of different plots

Transplanting of mustard

Wheat at 30 DAS

Phalaris minor in wheat weedy

Overview of Smothering potential of different intercrops on *Phalaris minor* in bed planting technology of wheat

Chapter 4 RESULTS AND DISCUSSION

The results of both the experiments are discussed experiment wise as under.

Experiment 1: Role of different *Rabi* crops for controlling *Phalaris minor* Retz. in comparison to wheat (*Triticum aestivum* L.)

4.1.1 Count of *Phalaris minor* per sq.m

Phalaris minor infestation in the cropped field directly influences the total crop yield depending upon its intensity. The count of *P.minor* at periodic intervals were monitored for different treatments to evaluate the role of different crop rotations on smothering *Phalaris minor*. Due to large variation in *Phalaris minor* count, the data was subjected to square root transformation. The data was analyzed after adding one to original values and by taking the under root. The weed data was recorded only for *Phalaris minor* the target weed. Counts of *Phalaris minor* was observed at 30, 60, 90 DAS and at harvest as shown in Table 4.1.1-a and Table 4.1.1-b and graphically shown in Fig 4.1.1. In the first year (2020-2021) at 30 DAS, the maximum count of *Phalaris minor* was found in wheat weedy (5.47) followed by African sarson (T) (5.07), African sarson (S) (4.97) and barley (4.97) which were significantly higher than other crops except raya (Table 4.1.1-a). The minimum count of *Phalaris minor* was found in wheat weed free treatment. Among alternate crops, the least count of *Phalaris minor* was found in berseem, oats and potato, which was significantly lower than wheat weedy treatment. Berseem had significantly lower count of *Phalaris minor* as compare to wheat weedy treatment. Count of *P. minor* in berseem was found at par with oats and potato based crop rotations. The count of *Phalaris minor* in oil crops was significantly less as compare to wheat weedy. The gobhi sarson transplanted had significantly lower count of *Phalaris minor* per square meter as compare to gobhi sarson seeded, African sarson seeded and transplanted and raya. The fennel had 43.65% lesser count of *Phalaris minor* than wheat weedy.

In the second year (2021-2022), the maximum count of *Phalaris minor* per sq.m. was found in wheat weedy (6.49) followed by African sarson (T) (5.51) and lentil (5.36) which were significantly higher than all tried alternate crops to wheat (Table 4.1.1-a). The minimum count of *Phalaris minor* per sq.m. was found in wheat weed free (1.0) which was significantly less as compare to other crop rotations. The least count of *Phalaris minor* was found in oats, berseem and potato which was significantly less than all other alternative crops to wheat. The gobhi sarson was found at par with raya with respect to count of *Phalaris minor*. The gobhi sarson transplanted had significantly lower count of *Phalaris minor* as compare to gobhi sarson seeded, African sarson seeded and transplanted crop.

In the pooled data (2020-21 and 2021-22) recorded at 30 DAS, the maximum count of *Phalaris minor* was found in wheat weedy treatment (5.98) followed by African sarson transplanted (5.29), African sarson seeded (5.13) and barley (5.05) and all these crops recorded significantly more count of *Phalaris minor* than all other crops except lentil (Table 4.1.1-a). The minimum count of *Phalaris minor* was found in wheat weed free treatment (0) which was significantly lower as compare to other crop rotations. The African sarson transplanted was found at par with African sarson seeded, barley and lentil with respect to weed count. The least count of *Phalaris minor* per sq.m. was found in oats, berseem and potato. Oats was found at par with berseem and potato with respect to count of *Phalaris minor*. The gobhi sarson transplanted was found at par with gobhi sarson seeded and raya with respect to count of *Phalaris minor*.

At 60 DAS, in the first year (2020-21) the maximum count of *Phalaris minor* was found in wheat weedy (6.98) followed by African sarson transplanted (6.41) and African sarson seeded (6.38). These cropping systems had significantly more count than other crops except gobhi sarson seeded (Table 4.1.1-a). The minimum count of *Phalaris minor* was found in wheat weed free treatment. Next to this crop, the least count of *Phalaris minor* was found in berseem, oats and potato, which were significantly lower than all wheat alternate cropping systems. Berseem was found at par with oats. The count of *Phalaris minor* in oil seed crops was significantly less as compare to wheat weedy. The raya had significantly lower count of *Phalaris minor* per sq.m. as compare to gobhi sarson seeded, African sarson seeded and transplanted. The fennel had significantly more count of *Phalaris minor* than berseem, oats and potato based cropping systems.

In the second year (2020-22) at 60 DAS, the maximum count of *P. minor* was found in wheat weedy (7.35) followed by African sarson transplanted (6.90) and African sarson seeded (6.77). Both had significantly more count than all other wheat alternate crops (Table 4.1.1-a). The minimum count of *Phalaris minor* was found in wheat weed free which was significantly less as compare to other crop rotations. The least count of *Phalaris minor* was found in oats, berseem and potato which was significantly less than all other alternative wheat crop rotations. The oats were found at par with berseem, potato-radish and potato-carrot crop rotations. The gobhi sarson transplanted was found at par with raya and gobhi sarson seeded with respect to count of *Phalaris minor* per sq.m.

In the pooled data (2020-21 and 2021-22) at 60 DAS, the maximum count of *P. minor* was found in wheat weedy treatment (7.16) followed by African sarson transplanted (6.66) and African sarson seeded (6.57) and all these crops recorded significantly more count of *Phalaris minor* except barley (6.31) than all alternate to wheat crops (Table 4.1.1-a). The minimum count of *Phalaris minor* was found in wheat weed free treatment. The wheat weed free cropping system had significantly low count as compare to all other crops. The African sarson transplanted was found at par with African sarson seeded and barley. The least count of *Phalaris minor* was found in oats, berseem and potato which were significantly less than other crops. The oats were found at par with berseem with respect to *Phalaris minor*. Also, the gobhi sarson transplanted was found at par with gobhi sarson seeded and raya for smothering *Phalaris minor*.

Phalaris minor count at 90 DAS became maximum but at the time of harvesting it decreased due to self competition. In the first year (2020-21) at 90 DAS, the maximum count of *Phalaris minor* was found in wheat weedy (8.82) followed by barley (7.66), African sarson seeded and transplanted which were significantly higher than other wheat alternative crops (Table 4.1.1-b). The minimum count of *Phalaris minor* was found in wheat weed free treatment. The least count of *Phalaris minor* was found in berseem, oats and potato, which was significantly lower than all other crops. Berseem had significantly lower count of *Phalaris minor* as compare to wheat weedy treatment. Berseem was found at par with oats and potato with respect to count of *Phalaris minor*. The count of *Phalaris minor* in oil seed crops was significantly less as compare to wheat weedy. The raya had significantly lower count of *Phalaris minor* as compare to gobhi sarson seeded and transplanted, African sarson seeded and transplanted. The fennel had significantly less count of *Phalaris minor* than wheat weedy, raya, berseem, lentil, oats and potato based cropping systems.

In the second year (2021-22), the maximum count of *Phalaris minor* per sq. m. was found in wheat weedy (9.05) followed by African sarson transplanted (7.98), African sarson seeded (7.33), gobhi sarson seeded (7.15), barley (7.31) and lentil (6.96) and all these crops reported significantly higher count of *P. minor* than other wheat alternative crops (Table 4.1.1-b). The minimum count of *Phalaris minor* was found in wheat weed free which was significantly less as

Table 4.1.1-a: Count of *P. minor* (per sq.m) at 30 and 60 DAS in different wheat alternative cropping systems

	Count of *Phalaris minor* (per sq.m.)					
	30 DAS			60 DAS		
Treatments	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
Wheat weedy	5.47 (29.0)	6.49 (41.3)	6.01 (35.1)	6.98 (47.8)	7.35 (53.0)	7.16 (50.4)
Wheat weed free	1.00 (0)	1.00 (0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
Gobhi sarson (S)	4.41 (18.5)	4.74 (21.5)	4.58 (20.0)	6.02 (35.3)	5.56 (30.0)	5.79 (32.9)
Gobhi sarson (T)	3.87 (14.0)	4.05 (15.5)	3.97 (14.8)	5.67 (31.3)	5.45 (28.8)	5.56 (30.0)
African sarson (S)	4.97 (23.8)	5.29 (27.0)	5.14 (25.4)	6.38 (39.8)	6.77 (45.0)	6.57 (42.4)
African sarson (T)	5.07 (24.8)	5.51 (29.5)	5.30 (27.1)	6.41 (40.3)	6.90 (46.8)	6.66 (43.5)
Raya	4.55 (19.8)	4.39 (18.3)	4.47 (19.0)	5.63 (30.8)	5.47 (29.0)	5.55 (29.9)
Barley	4.97 (23.8)	5.12 (25.3)	5.05 (24.5)	6.34 (39.3)	6.28 (38.5)	6.31 (38.9)
Berseem	3.29 (10.3)	2.80 (7.0)	3.10 (8.6)	2.28 (4.3)	2.22 (4.0)	2.25 (4.1)
Lentil	4.36 (18.0)	5.36 (27.8)	4.89 (22.9)	5.65 (31.0)	6.16 (37.0)	5.91 (34.0)
Potato-Radish	3.70 (12.8)	3.39 (10.5)	3.55 (11.6)	4.06 (15.5)	3.90 (14.3)	3.98 (14.9)
Potato-Carrot	3.76 (13.3)	3.60 (12.0)	3.69 (12.6)	4.41 (18.5)	3.81 (13.5)	4.11 (16.0)
Oats fodder & seed	3.53 (11.5)	2.52 (5.5)	3.08 (8.5)	2.37 (4.8)	2.05 (3.3)	2.21 (4.0)
Fennel	4.15 (16.3)	3.89 (14.3)	4.04 (15.3)	5.33 (27.5)	4.92 (23.3)	5.13 (25.4)
CD at 5%	0.43	0.44	0.46	0.38	0.39	0.31

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values √x+1

compare to other crop rotations. Also, the least count of *Phalaris minor* was found in berseem which was found at par with oats and potato. The African sarson transplanted gave significantly more count of *Phalaris minor* than barley. The raya had significantly lower count of *Phalaris minor* as compare to gobhi sarson seeded and transplanted, African sarson seeded and transplanted.

From the pooled data of 2020-21 and 2021-22, maximum count of *P. minor* was found in wheat weedy treatment (8.94) followed by African sarson transplanted (7.80), barley (7.49), African sarson seeded (7.36), gobhi sarson seeded (6.99) and all these crops recorded significantly more *Phalaris minor* count than all other crops except gobhi sarson transplanted (Table 4.1.1-b). The minimum count of *Phalaris minor* was found in wheat weed free treatment. This system had significantly lower count as compare to other treatments. African sarson transplanted was found at par with African sarson seeded and barley with respect to count of *Phalaris minor*. The significantly least count of *Phalaris minor* was found in oats, berseem and potato as compare to other crops. The berseem was found at par with oats and potato. Also, the gobhi sarson transplanted was found at par with gobhi sarson seeded and raya. The fennel recorded significantly more count of *Phalaris minor* than wheat weed free, berseem, oats and potato based cropping systems.

At harvesting time, in the first year (2020-21) the maximum count of *Phalaris minor* was found in wheat weedy (8.77) followed by barley (7.76) which was significantly more than other wheat alternative crops (Table 4.1.1-b). The less count of *Phalaris minor* was found in wheat weed free treatment as compared to all other alternate crops. Least count of *Phalaris minor* was found in berseem, oats and potato, which was significantly less than wheat weedy treatment. Potato-carrot was found at par with oats, potato-radish and berseem. The count of *Phalaris minor* in oil seed crops was significantly less as compare to wheat weedy. The raya had significantly lower count of *Phalaris minor* as compare to gobhi sarson seeded and transplanted, African sarson seeded and transplanted. The fennel had significantly less count of *Phalaris minor* than wheat weedy. Fennel was found at par with lentil.

In the second year (2021-22), the maximum count of *Phalaris minor* was found in wheat weedy (8.77) followed by African sarson transplanted (7.76) which was significantly more than other wheat alternative crops (Table 4.1.1-b). The minimum count of *Phalaris minor* was found in wheat weed free which was significantly less as compare to weed count in other crops. The least count of *Phalaris minor* was found in oats, berseem and potato which was significantly less than all wheat alternative crops. The potato- carrot was found at par with berseem, potato-radish and oats. The count of *Phalaris minor* in raya was significantly less as compare with Gobhi sarson seeded and transplanted and African sarson seeded and transplanted.

From the pooled data (2020-21 and 2021-22) it may be concluded that the maximum count of *Phalaris minor* was found in wheat weedy treatment (8.55) followed by African sarson transplanted (7.09) and barley (6.48) and all these crops recorded significantly more count of *Phalaris minor* as compare to other crops (Table 4.1.1-b). The minimum count of *Phalaris minor* at harvest was found in wheat weed free treatment. This system had significantly lower count as compare to other wheat alternative crops. The African sarson transplanted was found at par with African sarson seeded and barley. The least count of *Phalaris minor* was found in oats, berseem and potato which were significantly less than other crops. The potato-carrot was found at par with oats, berseem and potato-radish with respect to count of *Phalaris minor*. Also, raya was found at par with Gobhi sarson seeded, transplanted and lentil. The fennel was found at par with raya for the count of *Phalaris minor* per sq.m. These studies are in conformity with those of Singh *et al*., (2001), Malik and Singh (1993), Banga *et al.*, (1997) and Bhan and Kumar (1998). Similar results were found in second year and in the pooled data.

In berseem, potato and oats, count of *P minor* was significantly less than other crops because of reduction of *P minor* population either due to digging of potato or due to repeated cuttings of fodders. Under these crop rotations *Phalaris minor* plants were either uprooted or cut before the start of its reproductive stage.

Table 4.1.1-b: Count of *P. minor* (per sq.m) at 90 DAS and at harvest in different wheat alternative cropping systems

Treatments	Count of *Phalaris minor* (per sq. m.)					
	90 DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat weedy	8.82 (76.8)	9.05 (81.0)	8.94 (78.9)	8.34 (68.5)	8.77 (76.0)	8.55 (72.3)
Wheat weed free	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0)
Gobhi sarson (S)	6.82 (45.5)	7.15 (50.3)	6.99 (47.9)	6.28 (38.5)	6.12 (36.5)	6.20 (37.5)
Gobhi sarson (T)	6.57 (42.3)	6.48 (41.0)	6.53 (41.6)	6.28 (37.8)	5.65 (31.0)	5.97 (34.4)
African sarson (S)	7.39 (53.8)	7.33 (52.8)	7.36 (53.3)	6.38 (39.8)	7.02 (48.3)	6.70 (44)
African sarson (T)	7.61 (57.0)	7.98 (62.8)	7.80 (59.9)	6.42 (40.3)	7.76 (59.3)	7.09 (49.8)
Raya	6.42 (40.3)	5.89 (33.8)	6.16 (37.0)	5.87 (33.5)	5.31 (27.3)	5.59 (30.4)
Barley	7.66 (57.8)	7.31 (52.5)	7.49 (55.1)	7.42 (54.0)	6.48 (41.0)	6.95 (47.5)
Berseem	1.64 (1.8)	1.57 (1.5)	1.61 (1.6)	1.57 (1.5)	1.49 (1.3)	1.53 (1.4)
Lentil	5.63 (30.8)	6.96 (47.5)	6.30 (39.1)	5.54 (29.8)	6.01 (35.3)	5.78 (32.5)
Potato-Radish	2.95 (7.8)	2.59 (5.8)	2.77 (6.8)	1.57 (1.5)	1.49 (1.3)	1.53 (1.4)
Potato-Carrot	3.27 (9.8)	2.33 (4.5)	2.80 (7.1)	1.49 (1.3)	1.41 (1.0)	1.45 (1.1)
Oats fodder and seed	1.79 (2.3)	1.72 (2.0)	1.75 (2.1)	1.70 (2.0)	1.65 (1.8)	1.68 (1.9)
Fennel	6.15 (37.0)	5.63 (30.8)	5.89 (33.9)	5.38 (28.0)	4.47 (19.0)	4.93 (23.5)
CD at 5%	0.36	0.33	0.45	0.29	0.27	0.53

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values $\sqrt{x+1}$

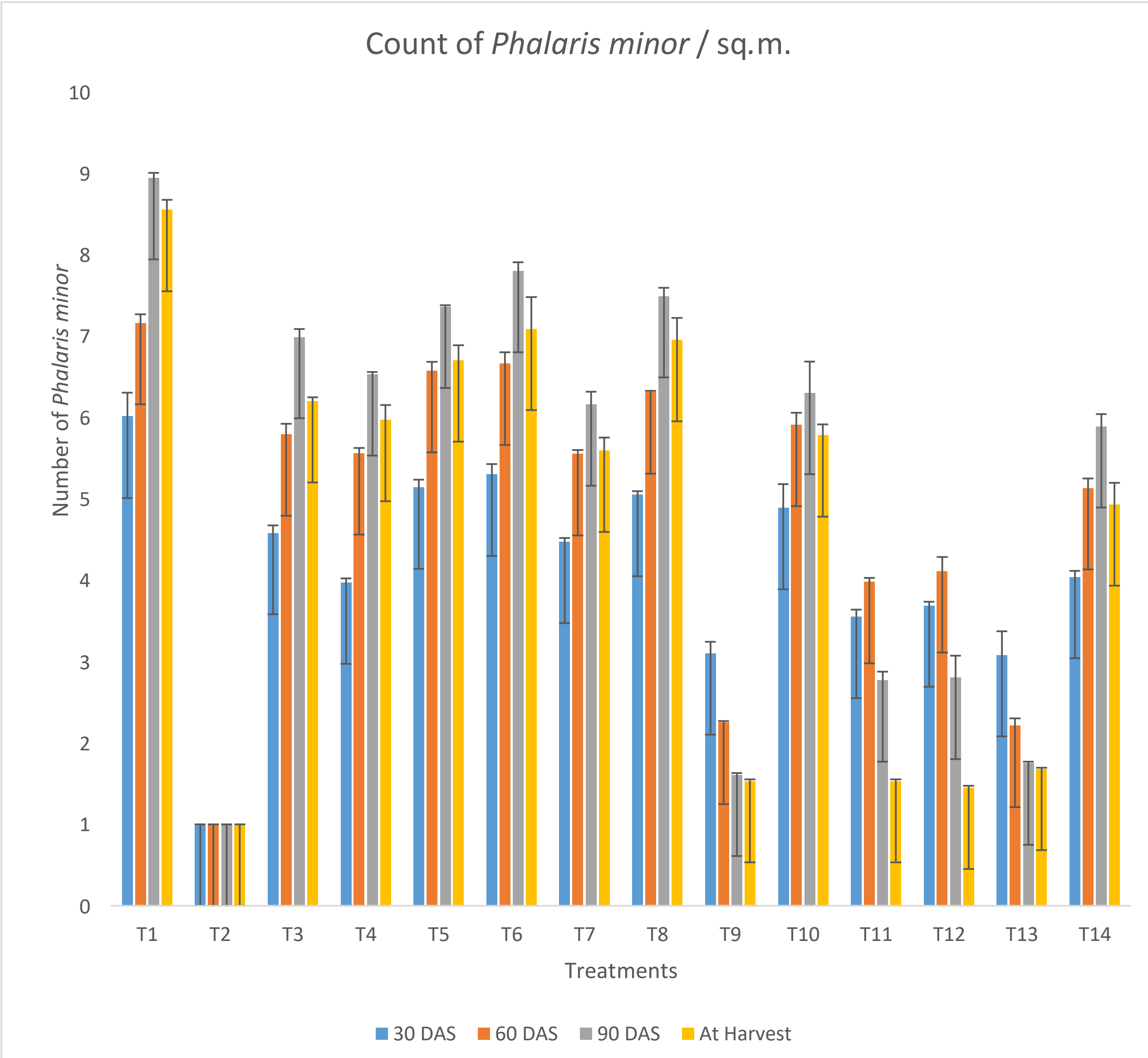


Fig. 4.1.1: Count of *P. minor* (per sq.m) in different wheat alternative cropping systems

Note: T1-Wheat weedy, T2-Wheat weed free, T3-Gobhi sarson seeded, T4-Gobhi sarson transplanted, T5-African sarson seeded, T6-African sarson transplanted, T7-Raya, T8-Barley, T9-Berseem, T10-Lentil, T11-Potato-Radish, T12-Potato-Carrot, T13-Oats fodder-seed, T14-Fennel

4.1.2 Dry matter of *Phalaris minor* (q/ha)

It is most essential parameter weeds which shows their competing ability or the effect of different treatments in smothering of weeds. Dry matter of weeds is most reliable parameter than weed count for estimating crop yield losses. Due to large variation in *Phalaris minor* count, the data was subjected to square root transformation. The data was analyzed after adding one to original values and by taking the under root The weed data was recorded only for *Phalaris minor* the target weed. Dry matter of *Phalaris minor* was recorded periodically at 30, 60, 90 DAS and at harvest as shown in Table 4.1.2-a and 4.1.2-b and graphically shown in Fig. 4.1.2. During the first year (2020-21) at 30DAS, significantly higher dry matter of *Phalaris minor* was found in wheat weedy (3.12 q/ha) followed by barley (2.48 q/ha) than other crops. The lowest DM of *Phalaris minor* was found in wheat weed free treatment. Berseem, oats and potato recorded significantly lower dry matter than all other alternate wheat crops. Berseem had significantly lower dry matter of *P. minor* as compare to wheat weedy treatment. Dry matter of *P. minor* in berseem was found at par with oats and potato. The dry matter of *Phalaris minor* in oil seed crops was significantly less as compare to wheat weedy. The DM(dry matter) accumulation of *P.minor* in raya was found at par with gobhi sarson seeded and transplanted and significantly less than African sarson. The fennel had significantly less dry matter of *Phalaris minor* than wheat weedy, barley and all brassica crops.

In the second year (2021-22) at 30 DAS, Significantly more dry matter of *Phalaris minor* was recorded in wheat weedy (3.41 q/ha) followed by barley (2.48 q/ha) as compared to all other crops (Table 4.1.2-a). The lower DM(dry matter) accumulation of *Phalaris minor* was found in wheat weed free which was significantly less as compare to other crops. The least dry matter of *Phalaris minor* was found in oats, berseem and potato which were significantly less than other wheat alternative crops. The berseem was found at par with oats and potato for accumulation of dry matter of *Phalaris minor*. Significantly lower dry matter of *Phalaris minor* was recorded in raya as compare to gobhi sarson seeded and transplanted, African sarson seeded and transplanted. The raya was found at par with gobhi sarson transplanted.

From the pooled data (2020-21 and 2021-220, maximum DM(dry matter) of *Phalaris minor* was found in wheat weedy treatment (3.27q/ha) followed by barley (2.48 q/ha) which was significantly higher as compare to other wheat alternate crops except African sarson transplanted

(Table 4.1.2-a). The least dry matter of *Phalaris minor* was found in oats, berseem and potato than all other crops. The berseem was found at par with oats and potato. Also, raya was found to produce significantly less dry matter of *Phalaris minor* than gobhi sarson seeded and transplanted. The fennel recorded significantly lesser dry matter of *Phalaris minor* than wheat weedy treatment.

In the first year (2020-21) at 60DAS, significantly higher dry matter of *Phalaris minor* was found in wheat weedy (5.31 q/ha), barley (4.69 q/ha), lentil (4.65 q/ha), African sarson seeded and transplanted which was more than all other alternate crops (Table 4.1.2-a). The significantly less dry matter of *Phalaris minor* was found in wheat weed free treatment as compared to all other wheat alternate crops. Berseem, oats and potato produced significantly less dry matter of *Phalaris minor* than all other crops. Berseem had significantly lower dry matter of *Phalaris minor* as compare to wheat weedy treatment. Dry matter of *Phalaris minor* in berseem was found at par with oats and significantly less than all other crops. The dry matter of *Phalaris minor* in oil seed crops was significantly less than wheat weedy. The raya had significantly less DM(dry matter) of *Phalaris minor* as compare to gobhi sarson seeded and transplanted. The fennel had significantly more dry matter of *Phalaris minor* than berseem, oats and potato based cropping systems.

In the second year (2021-22), significantly higher dry matter of *Phalaris minor* was found in wheat weedy (5.43 q/ha) followed by barley (4.73 q/ha) than all other crops Table (4.1.2-a). The lower dry matter of *Phalaris minor* was found in wheat weed free which was significantly less as compare to other crops. Also, the least dry matter of *Phalaris minor* was found in oats, berseem and potato based rotations which were significantly less than all other crops. The berseem was found at par with oats in terms of dry matter of *P.minor*. The raya had significantly lower dry matter of *Phalaris minor* as compare to gobhi sarson seeded and transplanted, African sarson seeded and transplanted. The lentil was found at par with African sarson transplanted with respect to dry matter of *Phalaris minor*. The fennel had significantly less dry matter of *Phalaris minor* than wheat weedy

From the pooled data recorded 60 DAS (2020-21 and 2021-22), the maximum dry matter of *Phalaris minor* was found in wheat weedy treatment (5.37 q/ha) followed by barley (4.71 q/ha), African sarson (seeded and transplanted) and lentil which was significantly higher as compare to other wheat alternative crops (Table 4.1.2-a). The lentil was found at par with African sarson transplanted with respect to dry matter of *Phalaris minor*. The least DM(dry matter) accumulation of *Phalaris minor* was found in oats, berseem and potato. DM of *P. minor* in berseem was found at par with oats. The raya had significantly lower dry matter of *Phalaris minor* as compare to gobhi sarson seeded and transplanted, African sarson seeded and transplanted. The fennel had significantly lesser dry matter of *Phalaris minor* than wheat weedy treatment, lentil, barley and all oil seed crops.

At 90DAS, the dry matter of *Phalaris minor* increased from 60 DAS but at the time of harvest the dry matter of *Phalaris minor* decreased slightly due to competition of weeds (Table 4.1.2-b). In the first year at 90 DAS, maximum dry matter of *Phalaris minor* was in found in wheat weedy (6.43 q/ha) followed by barley (5.97 q/ha) which was significantly more than other crops (Table 4.1.2-b). The dry matter of *Phalaris minor* found in wheat weed free treatment was significantly less than all other crops. The least dry matter of *Phalaris minor* was found in berseem, oats and potato, which was significantly lower than wheat weedy treatment, barley and mustard crops. Berseem was found at par with oats and potato in terms of DM accumulation by *Phalaris minor*. The dry matter of *Phalaris minor* in oil seed crops produced significantly less weed dry matter as compare to wheat weedy. The raya had significantly lower dry matter of *Phalaris minor* as compare to gobhi sarson seeded, African sarson seeded and transplanted. The fennel had significantly less dry matter of *Phalaris minor* than wheat weedy, barley, lentil and all oil seed crops.

In the second year (2021-22) at 90 DAS, the more DM of *Phalaris minor* was found in wheat weedy (6.49) followed by all Brassica crops (seeded and transplanted), barley and lentil and all these crops resulted in significantly more DM accumulation by *Phalaris minor* than all the remaining crops (Table 4.1.2-b). The less dry matter of *Phalaris minor* was found in wheat weed free which was significantly less as compare to other crops (Table 4.1.2-b). The least dry matter of *Phalaris minor* was found in berseem, oats and potato which were at par. Also, African sarson transplanted was found at par with barley. The raya had significantly lower dry matter of *Phalaris minor* as compare to barley, lentil, African sarson seeded and transplanted. The fennel had significantly higher dry matter as compare to berseem, oats and potato based cropping systems.

Table 4.1.2-a: Dry matter of *Phalaris minor* at 30 and 60DAS in different wheat alternative cropping systems

Treatments	Dry matter of *Phalaris minor* (q/ha)					
	30 DAS			60 DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat weedy	3.12 (8.77)	3.41 (10.64)	3.27 (9.71)	5.31 (27.24)	5.43 (28.50)	5.37 (27.87)
Wheat weed free	1.0 (0)	1.0 (0)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Gobhi sarson (S)	2.20 (3.84)	2.25 (4.06)	2.22 (3.95)	4.35 (17.92)	4.30 (17.53)	4.33 (17.72)
Gobhi sarson (T)	2.19 (3.79)	2.20 (3.84)	2.19 (3.82)	4.30 (17.48)	4.18 (16.59)	4.24 (17.03
African sarson (S)	2.22 (3.94)	2.29 (4.22)	2.25 (4.08)	4.56 (19.83)	4.65 (20.68)	4.61 (20.25)
African sarson (T)	2.33 (4.45)	2.41 (4.81)	2.37 (4.63)	4.61 (20.23)	4.68 (20.93)	4.65 (20.58)
Raya	2.10 (3.43)	1.99 (2.98)	2.05 (3.20)	4.12 (15.96)	4.03 (15.24)	4.07 (15.60)
Barley	2.48 (5.14)	2.48 (5.17)	2.48 (5.16)	4.69 (21.01)	4.73 (21.39)	4.71 (21.20)
Berseem	1.62 (1.65)	1.44 (1.08)	1.53 (1.36)	1.55 (1.41)	1.52 (1.33)	1.54 (1.37)
Lentil	2.03 (3.12)	2.25 (4.05)	2.14 (3.58)	4.65 (20.65)	4.51 (19.38)	4.58 (20.01)
Potato-Radish	1.76 (2.11)	1.56 (1.45)	1.66 (1.78)	3.06 (8.35)	2.24 (4.02)	2.65 (6.18)
Potato-Carrot	1.72 (1.98)	1.57 (1.48)	1.65 (1.73)	2.77 (6.84)	2.18 (3.74)	2.47 (5.29)
Oats fodder and seed	1.69 (1.85)	1.56 (1.43)	1.62 (1.64)	1.61 (1.63)	1.46 (1.13)	1.54 (1.38)
Fennel	1.98 (2.91)	1.84 (2.40)	1.91 (2.66)	3.39 (10.49)	3.28 (9.75)	3.33 (10.12)
CD at 5%	0.11	0.13	0.13	0.21	0.21	0.22

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values √x+1

As per pooled analysis (2020-21 and 2021-22) of data recorded 90 DAS (Table. 4.1.2.-b), the maximum dry matter of *Phalaris minor* was found in the wheat weedy treatment (6.46 q/ha) followed by barley (5.92 q/ha), lentil (5.76 q/ha) and African sarson transplanted (5.88 q/ha) which was significantly more than other crops (Table 4.1.2.-b). The barley was found at par with African sarson transplanted with respect to dry matter production by *P. minor*. The least dry matter of *Phalaris min*or was found in wheat weed free and this system had significantly low as compare to other treatments. Berseem, oats and potato were found at par with each other in terms of DM accumulation of *Phalaris minor* and significantly less than all other crops. The dry matter of *P. minor* in raya recorded at par with gobhi sarson seeded and transplanted. The fennel had significantly less dry matter of *Phalaris minor* than wheat weedy treatment, barley, lentil and other oil seed crops.

At harvesting time, in the first year (2020-21) the maximum dry matter of *Phalaris minor* was found in wheat weedy (6.21 q/ha) followed by barley (5.90 q/ha). These systems were significantly more than other crops except transplanted African sarson (Table 4.1.2-b). The minimum dry matter of *Phalaris minor* was observed in wheat weed free treatment which was succeded by berseem, oats and potato and all these crops produced significantly less dry matter of *Phalaris minor* than other cropping systems. The potato-radish was found at par with oats, potato-carrot and berseem with respect to dry matter accumulation by *Phalaris minor*. The dry matter of *Phalaris minor* in oil seed crops was significantly less as compare to wheat weedy. The raya had significantly less DM of *Phalaris minor* as compare to African sarson seeded and transplanted, barley and lentil. The fennel had significantly less dry matter of *Phalaris minor* than wheat weedy, barley, lentil and all oil seed crops.

During the second year (2021-22), the higher dry matter of *Phalaris minor* at harvest was found in wheat weedy (6.11) followed by African sarson transplanted and seeded, barley, lentil, gobhi sarson seeded and transplanted which was significantly more than all other crops (Table 4.1.2-b). The least dry matter of *Phalaris minor* was found in wheat weed free which was significantly less as compare to all other wheat alternative crops. The least dry matter of *Phalaris minor* was found in oats, berseem and potato which was significantly less than all other crops except potato based systems. The potato- radish was found at par with berseem, potato-carrot and oats. The dry matter of *Phalaris minor* in raya was significantly less as compare with African sarson seeded and transplanted, barley and lentil. The fennel had significantly less dry matter of *Phalaris minor* than wheat weedy.

From the pooled data (2020-21 and 2021-22) that, higher dry matter of *Phalaris minor* was found in wheat weedy treatment (6.16 q/ha) followed by barley, African sarson seeded and transplanted, lentil, gobhi sarson seeded and transplanted which were significantly higher than all other crops (Table 4.1.2-b). The lower dry matter of *P.minor* was found in wheat weed free treatment which was significantly lower as compare to other treatments. The barley was found at par with African sarson seeded and African sarson transplanted with respect to dry matter accumulation of. *P. minor*. The significantly less dry matter of *Phalaris minor* was found in oats, berseem and potato as compare to all other crops. The dry matter of *P. minor* in potato-radish was found at par with oats, berseem and potato-carrot. The fennel had significantly less dry matter of *Phalaris minor* than wheat weedy, barley, lentil and all oil seed crops.

From the basis of two years & pooled data, lowest dry matter accumulation by *Phalaris minor* (q/ha) was observed in berseem, oats and potato, grown instead of main cereal crop i.e., wheat. Among other crops, fennel was found more smothering than even Brassica crops. Same type of results were reported by Singh *et al*., (2001), Malik and Singh (1993), Banga *et al*., (1997) and Bhan and Kumar (1998). Vegetatively growing *Phalaris minor* plants were cut with the first cuttings of oats and berseem and this troublesome weed was not allowed to produce seed. Similarly at the time of digging of potato, all growing plants of *Phalaris minor* were uprooted.

Table 4.1.2-b: Dry matter of *Phalaris minor* (q/ha) at 90 DAS and at harvest in different wheat alternative cropping systems.

Treatments	Dry matter of *Phalaris minor* (q/ha)					
	90 DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat Weedy	6.43 (40.36)	6.49 (41.11)	6.46 (40.73)	6.21 (37.54)	6.11 (36.45)	6.16 (36.99)
Wheat weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Gobhi sarson (S)	5.63 (30.68)	5.42 (28.43)	5.53 (29.55)	5.43 (28.57)	5.26 (26.75)	5.35 (27.66)
Gobhi sarson (T)	5.41 (29.30)	5.32 (28.18)	5.37 (28.74)	5.10 (26.38)	4.87 (23.80)	4.99 (25.09)
African sarson (S)	5.82 (32.86)	5.84 (33.12)	5.83 (32.99)	5.64 (30.83)	5.65 (31.00)	5.65 (30.91)
African sarson (T)	5.86 (33.34)	5.89 (33.71)	5.88 (33.53)	5.71 (31.62)	5.82 (32.90)	5.77 (32.26)
Raya	5.50 (28.22)	5.40 (27.35)	5.45 (27.79)	5.23 (28.56)	4.98 (22.70)	5.11 (23.88)
Barley	5.97 (34.58)	5.88 (33.60)	5.92 (34.09)	5.90 (33.92)	5.64 (30.80)	5.77 (32.36)
Berseem	1.30 (0.69)	1.29 (0.66)	1.29 (0.68)	1.33 (0.76)	1.26 (0.60)	1.30 (0.68)
Lentil	5.91 (33.96)	5.61 (30.46)	5.76 (32.21)	5.57 (30.09)	5.40 (28.13)	5.49 (29.11)
Potato-Radish	1.39 (0.94)	1.36 (0.85)	1.38 (0.89)	1.19 (0.43)	1.19 (0.42)	1.19 (0.42)
Potato-Carrot	1.36 (0.86)	1.33 (0.76)	1.34 (0.81)	1.25 (0.57)	1.23 (0.51)	1.24 (0.54)
Oats fodder and seed	1.34 (0.81)	1.15 (0.32)	1.25 (0.56)	1.39 (0.973)	1.33 (0.79)	1.36 (0.88)
Fennel	3.92 (14.34)	3.73 (12.93)	3.82 (13.63)	3.67 (12.48)	3.02 (8.18)	3.35 (10.33)
CD at 5%	0.11	0.14	0.09	0.27	0.24	0.16

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values $\sqrt{x+1}$

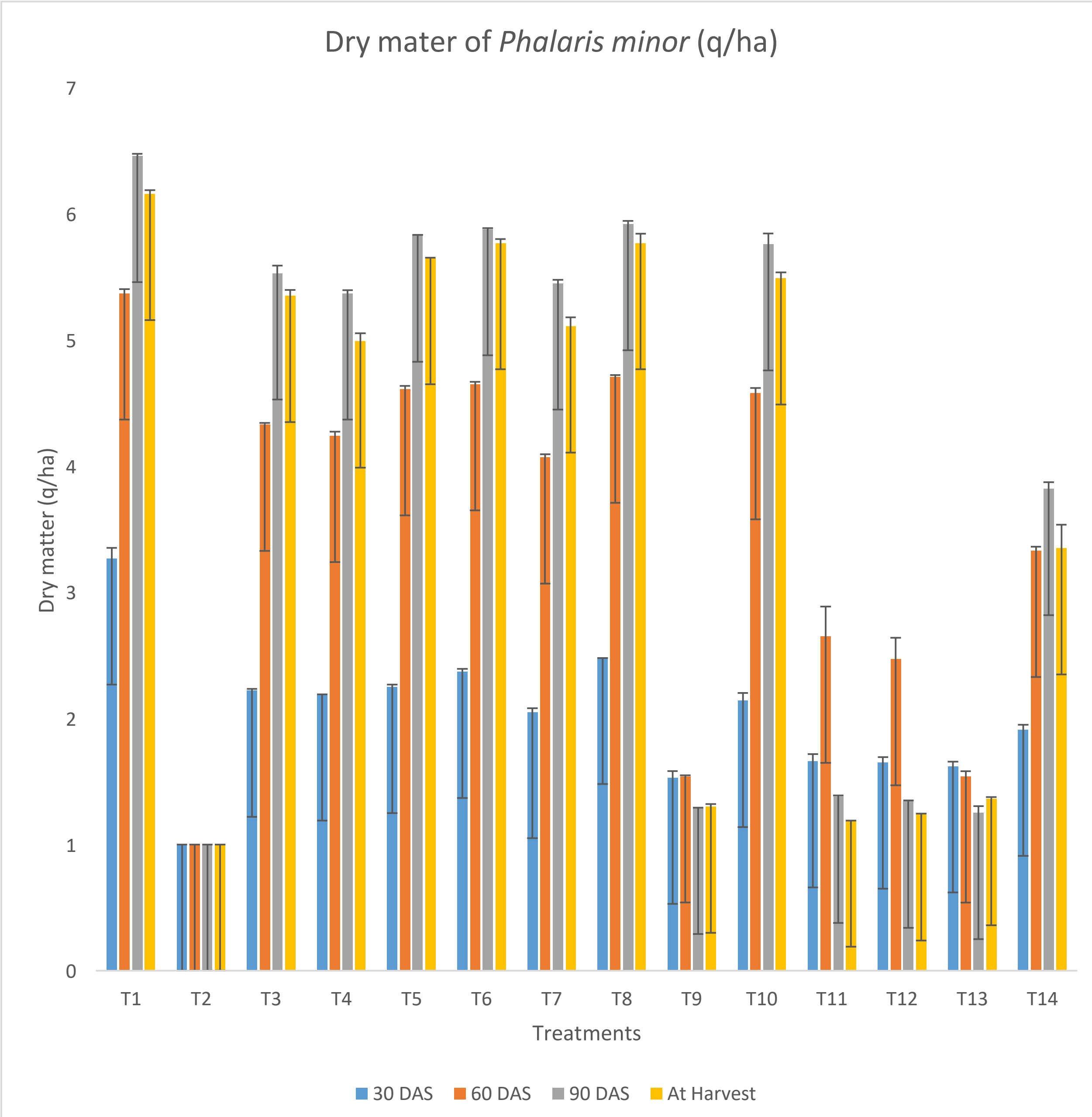


Fig. 4.1.2: Dry matter of *P. minor* (q/ha) in different wheat alternative cropping systems

Note: T1-Wheat weedy, T2-Wheat weed free, T3-Gobhi sarson seeded, T4-Gobhi sarson transplanted, T5-African sarson seeded, T6-African sarson transplanted, T7-Raya, T8-Barley, T9-Berseem, T10-Lentil, T11-Potato-Radish, T12-Potato-Carrot, T13-Oats fodder-seed, T14-Fennel

4.2. Growth and yield:

4.2.1 Plant height (cm)

Plant height is the furthermost parameter of plant development which helps to determine the growth rate and yield of the crop. The periodic plant height at 30, 60, 90 DAS and at harvest was shown in Table 4.2.1-a and 4.2.1-b. During the first year (2020-21) at 30 DAS, significantly maximum height was found in raya (23.9 cm) followed by oats (23.8 cm) and it was significantly higher as compared with wheat weedy (Table 4.2.1-a). These crop rotations were found at par with wheat weed free, barley, gobhi sarson (T) and bereem. The minimum height was found in lentil (11.7 cm) which was significantly lower than wheat weedy and wheat weed free and it was found at par with potato-carrot and potato-radish crop rotation. The crop rotation of gobhi sarson (S) was found at par with wheat weedy, African sarson (T) and fennel and it was significantly higher from lentil, potato-radish and potato-carrot crop rotation.

In the second year (2021-22) at 30DAS, the maximum height was found in raya (28.0 cm) followed by gobhi sarson (25.4 cm) and these two were significantly higher than all other treatments (Table 4.2.1-a). The minimum height was found in lentil (13.9 cm) which was significantly lower than wheat weedy and wheat weed free rotation and it was found at par with gobhi sarson (S), potato-carrot and potato-radish crop rotation. The crop rotation of barley was found at par with wheat weedy, African sarson (T) and fennel crop rotation and it was significantly higher from lentil, potato-radish and potato-carrot crop rotation. The crop rotation of African sarson (S) was recorded at par with wheat as weed free, berseem and oats.

From pooled data analysis (2020-21 and 2021-22), it had been observed that the significantly maximum height was found in raya (25.9 cm) followed by oats (24.1 cm) (Table 4.2.1-a). The minimum height was found in lentil (12.8 cm) which was significantly lower than wheat weedy and wheat weed free rotation and it was found at par with potato-carrot and potato-radish crop rotation. The crop rotation of fennel was found at par with wheat weedy and barley crop rotation and it was significantly higher from lentil, potato-radish and potato-carrot crop rotation. The crop rotation of berseem was recorded at par with wheat weed free, gobhi sarson (T) & oats.

During the first year (2020-21) at 60 DAS, significantly maximum height was found in raya (90.2 cm) followed by gobhi sarson (T) (71.8 cm) (Table 4.2.1-a). The minimum height was found in potato-radish (19.28 cm) which was significantly lower than wheat weedy and wheat weed free and it was found at par with potato-carrot crop rotation. The crop rotation of lentil (S) was found at par with berseem and it was significantly more from potato-radish & potato-carrot crop rotation. The African sarson (T) was found at par with African sarson (S). The crop rotation of fennel was found at par with wheat weedy and barley crop rotation.

In the second year (2021-22) at 60DAS, the maximum height was found in raya (94.9 cm) followed by gobhi sarson (T) (78.8 cm) and plant height of raya was significantly maximumr as compared with all other treatments (Table 4.2.1-a). The minimum height was found in potato-radish (25.6 cm) which was significantly lower than wheat weedy and wheat weed free rotation and it was found at par with potato-carrot crop rotation. The crop rotation of lentil (S) was at par with berseem and it was significantly higher from potato-radish and potato-carrot crop rotation. The crop rotation of fennel was found at par with African sarson (T) crop rotation.

From the analysis of pooled data (2020-21 and 2021-22), it was observed that the maximum height was found in raya (92.5 cm) followed by gobhi sarson (T) (75.3 cm) and raya and all these crops recorded significantly higher plant height as compared with all treatments (Table 4.1.3-a). The minimum height was found in potato-radish (25.6 cm) which was significantly lower than wheat weedy and wheat weed free rotation and it was found at par with lentil, potato-carrot crop rotation. The crop rotation of fennel was found at par with wheat weedy crop rotation. The African sarson (S) was found at par with gobhi sarson (S).

During the first year (2020-21) at 90 DAS, significantly maximum height was found in raya (137.1 cm) followed by gobhi sarson (T) (124.9 cm) and raya (137.1 cm) and these were significantly higher as compared with all treatments (Table 4.2.1-b). The minimum height was found in berseem (21.95 cm). It was observed that berseem had significantly lower plant height than all other treatments. The African sarson (T) was found at par with wheat weedy. Both the gobhi sarson seeded and transplanted had significantly higher plant height as compare with wheat weedy and weed free.

Table 4.2.1-a: Plant height (cm) of different crops in variable wheat alternative cropping systems.

Treatments	Plant height (cm)					
	30 DAS			60 DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat weedy	18.2	19.7	18.9	32.9	39.9	36.4
Wheat weed free	23.5	24.1	23.8	44.9	58.8	51.9
Gobhi sarson (S)	15.3	15.6	15.4	62.4	65.9	64.2
Gobhi sarson (T)	21.5	25.4	23.4	71.8	78.8	75.3
African sarson (S)	19.4	22.8	21.1	56.5	63.0	59.8
African sarson (T)	18.1	17.2	17.7	52.9	44.6	48.8
Raya	23.9	28.0	25.9	90.2	94.9	92.5
Barley	21.5	17.2	19.4	36.6	49.3	42.9
Berseem	21.6	24.7	23.2	25.7	29.3	27.5
Lentil	11.7	13.9	12.8	25.8	31.3	28.5
Potato-Radish	13.2	15.6	14.4	19.3	25.6	22.5
Potato-Carrot	12.0	14.8	13.4	20.5	25.8	23.1
Oats fodder-seed	23.8	24.5	24.1	41.7	61.3	51.5
Fennel	17.2	19.58	18.36	32.7	48.4	40.5
CD at 5%	2.90	3.00	1.89	4.60	4.89	5.64

In the second year (2021-22) at 90DAS, significantly maximum height was found in raya (146.8 cm) followed by gobhi sarson (T) (132.6 cm) (Table 4.2.1-b). The significantly minimum height was found in berseem (23.3 cm). The lentil was found at par with potato-radish and potato-carrot crop rotation. The African sarson (T) was found at par with wheat weedy. Bothe the gobhi sarson seeded and transplanted had significantly higher plant height as compare with wheat weedy and weed free.

From the analysis of pooled data (2020-21 and 2021-22) at 90 DAS, it had been observed that the maximum height was found in raya (141.9 cm) followed by gobhi sarson (T) (128.7 cm) and height of raya was significantly higher as compared with all other treatments (Table 4.2.1-b). The significantly minimum height was found in berseem (22.6 cm). The lentil was found at par with oats crop rotation. The crop rotation of potato-radish was found at par with potato-carrot crop rotation. The wheat weed free was recorded at par with African sarson (T). Both the gobhi sarson seeded and transplanted had significantly higher plant height as compare with wheat weedy and weed free.

At harvesting time (2020-21), the maximum height was found in gobhi sarson (T) (167.6 cm) followed by raya and it was significantly higher as compared with all other treatments (Table 4.2.1-b). The berseem (34.1 cm) had significantly minimum plant height. Both the gobhi sarson and African sarson seeded and transplanted had significantly higher plant height as compare with wheat weedy and weed free. The barley was found significantly superior to potato-radish, potato-carrot, berseem, lentil and oats crop rotations with respect to plant height.

In the second year (2021-22) at harvest, the maximum height was found in gobhi sarson (T) (173.8 cm) followed by raya and was significantly higher as compared with all treatments (Table 4.2.1-b). The berseem (30.0 cm) had significantly minimum height. Both the gobhi sarson seeded and transplanted had significantly higher plant height as compare with wheat weedy and weed free. The oats was found at par with potato-radish and potato-carrot crop rotation. The African sarson (T) was recorded at par with wheat weed free.

From the analysis of pooled data (2020-21 and 2021-22), it was observed that the maximum height was found in gobhi sarson (T) (170.7 cm) followed by raya and was significantly higher as compared with all treatments (Table 4.2.1-b). The minimum height was found in berseem (32.1 cm). Both the gobhi sarson seeded and transplanted had significantly higher plant height as compare with wheat weedy and weed free. The barley was found at par with potato-radish and potato-carrot crop rotation. The African sarson (T) was found at par with wheat weed free. The results are in conformity with those of Banga *et al.*, (1997), Bhan and Kumar (1998) and Singh *et al*.,(2001).

The research data generated was analyzed statistically for its scientific presentation and to draw valid conclusions. The difference in plant height of variable crops was only due to their genetically characteristics and not due to agronomic variations including competition by *Phalaris minor*. Brassica crops had genetically more height than all other crops followed by cereals crops like wheat, barley and oats. However, the plant height of berseem, potato is genetically less. Fennel height resembles with cereals genetically.

Table 4.2.1-b: Plant height (cm) of different crops in variable wheat alternative cropping systems.

Treatments	Plant height (cm)					
	90 DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat weedy	76.6	76.6	76.6	78.5	78.1	78.3
Wheat weed free	91.9	94.7	93.3	103.0	103.9	103.4
Gobhi sarson (S)	113.1	125.9	119.5	158.6	169.3	163.9
Gobhi sarson (T)	124.9	132.6	128.7	167.6	173.8	170.7
African sarson (S)	87.3	109.9	98.6	117.9	144.4	131.2
African sarson (T)	73.7	97.3	85.5	108.8	103.4	106.1
Raya	137.1	146.7	141.9	160.9	172.8	166.9
Barley	66.1	70.1	68.1	88.4	95.1	91.7
Berseem	22.0	23.3	22.6	34.1	30.0	32.1
Lentil	33.3	44.6	38.9	41.8	59.9	50.9
Potato-Radish	50.8	48.3	49.6	87.7	93.5	90.6
Potato-Carrot	59.9	47.1	53.5	95.7	97.7	96.7
Oats fodder-seed	37.2	40.7	38.9	80.8	95.2	87.9
Fennel	73.0	81.5	77.2	111.3	132.2	121.8
CD at 5%	4.95	6.91	8.01	4.98	4.57	7.99

4.2.2 Dry matter of crops (q/ha)

Dry matter influences final crop yield, as it also reflects on the photosynthetic accumulation. Dry matter of crop increases at faster rate up to maturity. Data on periodic crop dry matter of different crops are shown in Table 4.2.2-a and 4.2.2-b and graphically shown in Fig. 4.1.3. During the first year (2020-21) at 30 DAS, the maximum DM accumulation was recorded in gobhi sarson transplanted (6.7 q/ha). Gobhi sarson was found at par with wheat weed free and gobhi sarson (S) and all these crops produced significantly higher dry matter as compare with wheat weedy (Table 4.2.2-a). The minimum dry matter was found in potato-carrot (1.13q/ha) which was found at par with potato-radish, fennel, lentil and berseem crop rotation. The African sarson transplanted was found at par with African sarson seeded and oats.

In the second year (2021-22) at 30 DAS, significantly maximum DM(dry matter) was recorded in gobhi sarson transplanted (6.7 q/ha) and was at par with wheat weed free and all these crops had significantly higher dry matter as compare with wheat weedy (Table 4.2.2-a). The minimum dry matter was found in potato-carrot (1.1 q/ha). It was at par with potato-radish, fennel, lentil and berseem crop rotation. The African sarson seeded was found at par with raya and oats. The barley was found at par with gobhi sarson seeded.

From the pooled data (2020-21 and 2021-22) recorded 30 DAS, it was concluded that the maximum dry matter was found in gobhi sarson transplanted (7.2 q/ha). The dry matter of gobhi sarson transplanted was recorded at par with wheat weed free which was significantly higher as compare with wheat weedy (Table 4.2.2-a). The minimum dry matter was found in potato-carrot (1.1 q/ha). This system was recorded at par with potato-radish, fennel crop rotation. Lentil was found at par with berseem crop rotation. The African sarson seeded was found at par with raya. The barley was found at par with gobhi sarson seeded.

During the first year (2020-21) at 60 DAS, the maximum DM was found in raya (25.4 q/ha) followed by gobhi sarson transplanted (25q/ha) which was significantly higher as compare with wheat weedy and wheat weed free (Table 4.2.2-a). The minimum dry matter was found in potato-carrot (2.9 q/ha). This system was recorded at par with potato-radish & berseem. The wheat weedy was found at par with lentil crop rotation. The wheat weed free was found at par with gobhi sarson seeded and barley.

In the second year (2021-22) at 60 DAS, the higher DM was found in gobhi sarson transplanted (28.6 q/ha) followed by barley (26.6 q/ha) and both these crops produced significantly higher as compare with wheat weedy and wheat weed free (Table 4.2.2-a). The wheat weed free was found at par with raya and fennel. The minimum dry matter was found in potato-carrot (3.1 q/ha) which was found at par with potato-radish and berseem. The wheat weedy was found at par with lentil crop rotation.

In the pooled data (2020-21 and 2021-22) at 60 DAS, the maximum DM was found in gobhi sarson transplanted (26.8 q/ha) which was found at par with raya, barley, fennel and wheat weed free (Table 4.2.2-a). The minimum dry matter was found in potato-carrot (3 q/ha) which was found at par with potato-radish, berseem and wheat weedy. The African sarson seeded was found at par with African sarson transplanted.

In the first year (2020-21) at 90 DAS, the significantly maximum DM was found in barley (44.2 q/ha) followed by wheat weed free (42.6 q/ha) (Table 4.2.2-b). The significantly minimum dry matter was found in berseem (3.1 q/ha). The African sarson seeded was found at par with African sarson transplanted. The potato- carrot was found at par with potato-radish crop rotation. From the oil seed crop, the significantly maximum dry mater was found in gobhi sarson transplanted.

In the second year (2021-22) at 90 DAS, the maximum dry matter was found in barley (45.7 q/ha) which was significantly higher than all other treatments followed by wheat weed free (43.6 q/ha) (Table 4.2.2-b). The minimum dry matter was found in berseem (3.2 q/ha) which was significantly lower than all other treatments. The fennel was found at par with raya crop rotation. The potato- carrot was found at par with potato-radish crop rotation. From the oil seed crop, the significantly maximum dry mater was found gobhi sarson transplanted.

From the pooled data analysis (2020-21 and 2021-22), significantly maximum dry matter was found in barley (45.0 q/ha). It had been observed that barley was significantly higher than all other treatments except wheat weed free (43.1 q/ha) (Table 4.2.2-b). The minimum dry matter was found in berseem (3.2 q/ha). This system was significantly lower than all other treatments.

Table 4.2.2-a: Periodic dry matter accumulation (q/ha) by different crops

Treatments	Dry matter accumulation by different crops (q/ha)					
	30DAS			60DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat weedy	2.6	2.3	2.4	7.6	7.3	7.5
Wheat weed free	6.3	7.5	6.9	20.4	25.2	22.8
Gobhi sarson (S)	6.0	6.7	6.4	19.4	24.1	21.8
Gobhi sarson (T)	6.7	7.8	7.2	25.0	28.6	26.8
African sarson (S)	4.6	4.9	4.7	13.2	14.2	13.7
African sarson (T)	3.8	3.4	3.6	11.0	10.3	10.7
Raya	4.8	5.0	4.9	25.4	25.5	25.4
Barley	5.9	6.3	6.1	21.6	26.6	24.1
Barseem	1.8	1.9	1.9	3.2	3.24	3.2
Lentil	1.7	1.5	1.6	8.4	7.9	8.2
Potato-Radish	1.2	1.2	1.2	3.0	3.4	3.2
Potato-Carrot	1.1	1.1	1.1	2.9	3.1	3.0
Oats fodder & seed	4.6	5.0	4.8	14.4	12.3	13.4
Fennel	1.3	1.6	1.5	23.8	25.1	24.5
CD at 5%	0.82	0.81	0.40	1.39	0.76	1.75

The potato- carrot was found at par with potato-radish crop rotaton. From the oil seed crop, the significantly higher dry mater was found gobhi sarson. The African sarson seeded was found at par with African sarson transplanted.

In the first year (2020-21) at harvest, the maximum dry matter was found in barley (60.3 q/ha) which was significantly higher than all other treatments except wheat weed free (59.3 q/ha) (Table 4.2.2-b). The minimum dry matter was found in berseem (2.1 q/ha) which was significantly lower than all other treatments. The African sarson seeded was found at par with wheat weedy. The gobhi sarson transplanted was found at par with oats with respect to crop dry matter. The potato- carrot was found at par with potato-radish crop rotation. From the oil seed crop, the significantly maximum dry mater was found in gobhi sarson transplanted than wheat weedy and other oil seed crops followed by raya.

In the second year (2021-22) at harvest, the higher crop DM(dry matter) was found in barley (64.7 q/ha). It had been observed that barley was significantly higher than all other treatments followed by wheat weed free (59.3 q/ha) (Table 4.2.2-b). The minimum dry matter was found in berseem (3.04 q/ha) which was significantly lower than all other treatments. From the oil seed crop, the significantly maximum dry mater was found in gobhi sarson transplanted followed by raya.

From the pooled data analysis (2020-21 and 2021-22), the maximum DM(dry matter accumulation) was found in barley (62.5 q/ha). Significantly barley had higher DM(dry matter) than all other treatments except wheat weed free (61.2 q/ha) (Table 4.2.2-b). The minimum dry matter was found in berseem (2.6 q/ha) which was significantly lower than all other treatments. The African sarson seeded was found at par with wheat weedy. The gobhi sarson transplanted was found at par with oats. The African sarson transplanted was found at par with potato-radish crop rotation. From the oil seed crop, the significantly maximum dry mater was found gobhi sarson transplanted followed by raya. Theses result are in conformity with those of Banga *et al.,* (1997), Bhan and Kumar (1998) and Singh *et al*.,(2001).

There is lot of variations in dry matter accumulation by different crops which may be due to their genetic characters and not due to any variation in agronomic pratices. Dry matter was highest in cereal crops (wheat, barley and oats) which was followed by oil seed crops. Genetically lentil and potato produces lower crop dry matter.

Table 4.2.2-b: Periodic dry matter accumulation (q/ha) by different crops

Treatments	Dry matter accumulation by different crops (q/ha)					
	90DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat weedy	22.3	20.9	21.6	30.2	29.1	29.7
Wheat weed free	42.6	43.6	43.1	59.3	63.1	61.2
Gobhi sarson (S)	29.9	30.1	30	34.2	35.6	34.9
Gobhi sarson (T)	37.2	38.2	37.7	44.8	46.7	45.8
African sarson (S)	24.4	25.3	24.9	30.1	31.8	31.0
African sarson (T)	23.9	22.1	23	27.4	25.2	26.3
Raya	32.6	35.8	34.2	43.2	44.1	43.7
Barley	44.2	45.7	45.0	60.3	64.7	62.5
Barseem	3.12	3.22	3.17	2.1	3.04	2.57
Lentil	12.4	11.4	11.9	15.3	15.97	15.6
Potato-Radish	5.6	6.2	5.9	24.2	26.8	25.5
Potato-Carrot	5.1	5.7	5.4	23.1	23.8	23.5
Oats fodder & seed	25.3	28.6	27.0	45.6	48.3	47.0
Fennel	28.4	35.4	31.9	37.8	40.1	38.9
CD at 5%	0.85	0.70	1.9	1.26	1.31	1.47

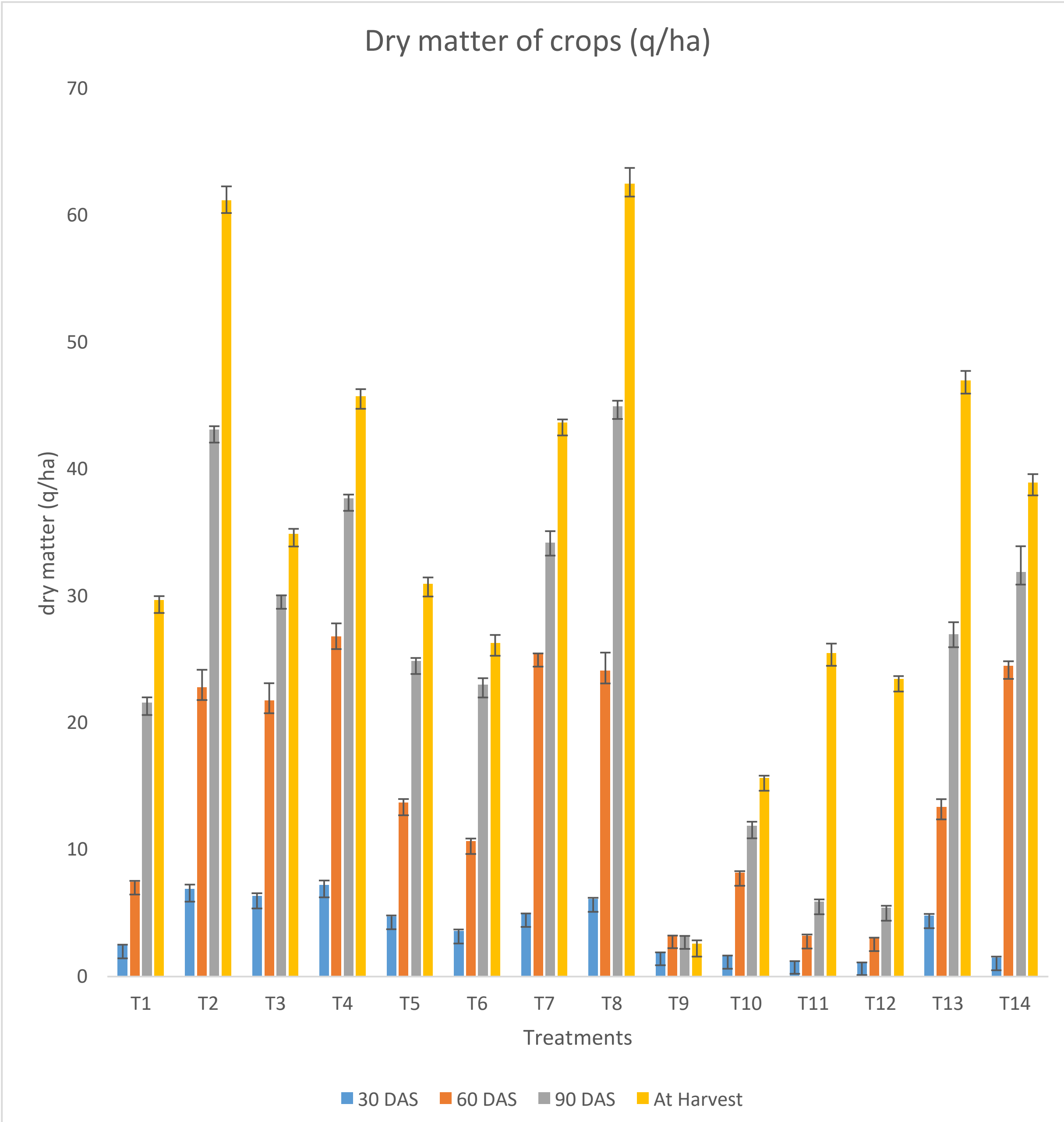


Fig. 4.1.3: Periodic dry matter accumulation by different crops

Note: T1-Wheat weedy, T2-Wheat weed free, T3-Gobhi sarson seeded, T4-Gobhi sarson transplanted, T5-African sarson seeded, T6-African sarson transplanted, T7-Raya, T8-Barley, T9-Berseem, T10-Lentil, T11-Potato-Radish, T12-Potato-Carrot, T13-Oats fodder-seed, T14-Fennel

4.3 Yield and yield attributes

4.3.1 Spike length (cm)

The spike length/ pod length influences the final crop yield, as number of grains usually increases with the increased spike length. The data relevant to spike length of different crops is described in Table 4.3.1. In the first year (2020-21), the maximum spike length was found in barley (10.12 cm) followed by wheat weed free treatment (9.25 cm) and these were significantly more than all other crops. In the wheat weedy treatment, the spike length significantly decreased as compare to wheat weed free treatment. The significantly more pod length was found in gobhi sarson transplanted (6.85cm) followed by gobhi sarson seeded (5.32cm) which was significantly higher as compare to other mustard crops. The pod length of gobhi sarson transplanted was 28.75% larger as compare to pod length of gobhi sarson seeded. The pod length of African sarson transplanted was found at par with African sarson seeded. The pod length of raya was found at par with radish. The minimum pod length was found in lentil (1.82 cm) which was significantly lower as compare to others. The spikelet of oats was significantly more as compare to pods of lentil.

In the second year (2021-22), the significantly maximum spike length was found in barley (11.53 cm) followed by wheat weed free treatment (10.05 cm) Table 4.3.1. In the wheat weedy treatment, the spike length was significantly less as compare to wheat weed free treatment. The maximum pod length was found in gobhi sarson transplanted (6.9cm) followed by gobhi sarson seeded (5.47cm) which was significantly higher than African sarson and raya. The pod length of gobhi sarson transplanted was 26.14% more as compare to pod length of gobhi sarson seeded. The pod length of African sarson transplanted was at par with African sarson seeded. The pod length of raya was statistically at par with radish. The minimum pod length was found in lentil (1.97cm) which was significantly lower as compare to other crops. The spikelets of oats were significantly more as compare to pods of lentil.

As indicated by pooled analysis of 2020-21 and 2021-22, the maximum spike length was found in barley (10.83 cm) followed by wheat weed free treatment (9.65 cm) which were significantly more than all other crops (Table 4.3.1). In the wheat weedy treatment, the spike length was significantly less as compare to wheat weed free treatment. The significantly more pod length was found in gobhi sarson transplanted (6.88 cm) than gobhi sarson seeded (5.40 cm). The pod length of gobhi sarson was significantly higher than African sarson and raya. The pod length of gobhi sarson transplanted was 21.51% more as compare to pod length of gobhi sarson seeded. The pod length of African sarson transplanted was found at par with African sarson seeded. The pod length of raya was at par with radish. The minimum pod length was found in lentil (1.90 cm) which was significantly lower as compare to pod length of other crops. The spikelets of oats were significantly more than pod length of lentil. The variations of pod length of different crops may be due to genetic variation in crop plants.

Table 4.3.1: Spike length/ pod length (cm) of different crops

Treatments	**Spike length/ Pod length (cm)**		
	2020-21	**2021-22**	**Pooled**
Wheat weedy	7.42	6.6	7.01
Wheat weed free	9.25	10.05	9.65
Gobhi sarson (S)	5.32	5.47	5.40
Gobhi sarson (T)	6.85	6.9	6.88
African sarson (S)	4.37	4.65	4.51
African sarson (T)	4.15	4.05	4.10
Raya	4.48	4.9	4.69
Barley	10.12	11.53	10.83
Lentil	1.82	1.97	1.90
Potato-Radish	4.77	4.95	4.86
Oats fodder-seed	2.95	3.37	3.16
CD at 5%	0.59	0.66	0.35

4.3.2 Number of grains per spike

Number of grains per spike/pod directly affects the yield. The data pertaining to the number of grains per spike/ pod is shown in Table 4.3.2. During the first year (2020-21) at 30 DAS, significantly barley had higher number of grains per spike (48.32) and wheat weed free (41.73). The wheat weedy was found at par with oats. The least number of grains was found in lentil crop rotation which was found at par with potato-radish crop rotation. The number of seeds per pod in oil seed crops had significantly less count as compare to barley and wheat. The African sarson transplanted had significantly lower count of seeds per pod as compare to African sarson seeded, gobhi sarson transplanted and raya. It was found at par with gobhi sarson seeded. Significantly raya had higher number of seeds per pod than other oil seed crop except gobhi sarson transplanted.

In the second year (2021-22), at 30 DAS, significantly higher number of grains per spike was found in barley (50.37) followed by wheat weed free (42.25) (Table 4.3.2). The least number of grains were found in lentil crop which was found at par with radish. The number of seeds per pod in oil seed crops had significantly less count as compare to barley and wheat. The African sarson transplanted had significantly lower count of seeds per pod as compare to gobhi sarson transplanted and raya. Number of seeds per pod in African sarson seeded were found at par with gobhi sarson seeded. The raya had significantly higher number of seeds per pod than other oil seed crop.

From the pooled data (2020-21 and 2021-22), the higher number of grains per spike were found in barley (49.34) followed by wheat weed free (41.73) (Table 4.3.2). The least number of grains were found in lentil which was found at par with radish. The number of seeds per pod in oil seed crops showed significantly less count as compare to barley and wheat. The African sarson transplanted had significantly lower count of seeds per pod as compare to gobhi sarson transplanted and raya seeded which were found at par with gobhi sarson seeded. The raya had significantly more number of seeds per pod than other oil seed crop.

Table 4.3.2:.Number of grains per spike/pods

Treatments	Number of seeds/grains per spike/pod		
	2020-21	**2021-22**	**Pooled**
Wheat weedy	30.84	32.72	31.78
Wheat weed free	41.73	42.25	41.99
Gobhi sarson (S)	9.78	10.25	10.02
Gobhi sarson (T)	14.50	15.53	15.01
African sarson (S)	13.36	11.65	12.51
African sarson (T)	9.53	10.92	10.22
Raya	16.96	18.35	17.65
Barley	48.32	50.37	49.34
Barseem	-----	-----	-----
Lentil	3.43	4.13	3.78
Potato-Radish	4.71	5.83	5.27
Potato-Carrot	-----	-----	------
Oats fodder & seed	32.20	34.73	33.46
Fennel	-----	------	------
CD at 5%	2.54	1.74	0.90

4.3.3 Test weight (1000 grain weight) (g)

1000 grain weight depends upon size and development of grain. Grain weight is a influenced by various environment conditions prevailing at grain filling periods. The data related to test weight has been shown in Table 4.3.3. During 2020-21, it had been observed that the significantly maximum test weight was found in barley (43.28 g) followed by wheat weed free (40.10 g). The least test weight was found in carrot (2.84 g) which was found at par with fennel, African sarson transplanted and African sarson seeded. The gobhi sarson seeded was found at par with gobhi sarson transplanted and raya. The test weight of oats was recorded at par with wheat weedy.

In the second year (2021-22), the maximum test weight was found in barley (45.35 g) followed by wheat weed free (41.03 g) (Table 4.3.3). Significantly least test weight was found in carrot (3.25 g) and at par with fennel, gobhi sarson seeded, gobhi sarson transplanted, African sarson transplanted and African sarson seeded. From the oil seed crops, the maximum test weight was found in raya and minimum was found in African sarson transplanted. The oats was at par with wheat weedy in terms of test weight.

From the analysis of pooled data (2020-21 and 2021-22), the maximum test weight was found in barley (44.31 g) followed by wheat weed free (40.56 g) (Table 4.3.3). The significantly lower test weight was recorded in carrot (3.04 g). The gobhi sarson seeded found at par with fennel, and gobhi sarson transplanted. The African sarson transplanted was at par with African sarson seeded. From the oil seed crops, the maximum test weight was found in raya and minimum was found in African sarson transplanted. The test weight of oats was at par with wheat weedy.

Table 4.3.3: Test weight of different crops (gm) in variable wheat alternative cropping systems

Treatments	Test weight (gm)		
	2020-21	2021-22	Pooled
Wheat weedy	38.08	37.75	37.91
Wheat weed free	40.10	41.03	40.56
Gobhi sarson (S)	4.49	4.53	4.51
Gobhi sarson (T)	4.59	4.62	4.60
African sarson (S)	4.10	4.18	4.14
African sarson (T)	4.06	3.83	3.94
Raya	5.36	5.41	5.38
Barley	43.28	45.35	44.31
Barseem	0.00	0.00	0.00
Lentil	24.93	23.72	24.33
Radish	10.48	11.95	11.21
Carrot	2.84	3.25	3.04
Oats fodder & seed	37.08	38.38	37.73
Fennel	4.14	4.32	4.23
CD at 5%	1.34	1.39	0.71

4.3.4 Yield (q/ha)

Data on yield of different alternative crops to wheat are shown in Table 4.3.4 and graphically represented in Fig. 4.1.4. Crop yield depends upon its weed control potential as well as on growth and yield attributes. The highest yield was found in fodder berseem crop (406.75q/ha) which was followed by oats fodder and seeds (316.5q/ha) and both these crops gave significantly higher yield than all other crops. The minimum yield was found in African seeded crop which was significantly lower as compare with berseem, oats, barley, wheat weed free and potato. The African sarson seeded was statistically at par with gobhi sarson seeded and transplanted, raya, lentil and fennel crop. From the mustard crop, the maximum yield was found in raya (13.25q/ha) followed by gobhi sarson transplanted (11.50q/ha). Raya had 15.21% more yield as compare to gobhi sarson transplanted. Transplanted mustard (gobhi sarson and African sarson) gave 28.26% and 28.57% respectively higher yield as compare to seeded crops. Potato-Carrot was recorded statistically at par with potato-radish. The wheat weedy treatment was significantly less than wheat weed free treatment and barley. The *Phalaris minor* decreased 46.09% yield in wheat weedy treatment as compare with wheat weed free treatment.

During the second year (2021-22), the yield level of different crops were slightly higher than first year which may be due to more favourable conditions. The significantly maximum yield was found in berseem crop (457.78 q/ha) and oats fodder and seed than all other crops (Table 4.3.4). The yield of berseem, oats and potato were significantly higher as compare with other treatments. The minimum yield was found in the African sarson transplanted which was significantly lower as compare with berseem, oats, barley, wheat weed free and potato. Among the mustard crop, the maximum yield was found in raya (14.97q/ha) followed by gobhi sarson transplanted (11.84q/ha) and African sarson. The yield of African sarson was statistically at par with gobhi sarson, raya, fennel and lentil crop. The transplanting of gobhi sarson increased yield by 26.22% as compare with gobhi sarson seeded whereas yield of African sarson transplanted was 6% more than African sarson seeded. Potato-Carrot produced yield at par with Potato-Radish. The yield of wheat weedy treatment was significantly lower as compare with wheat weed free treatment and barley. The *Phalaris minor* decreased 59.05% yield in wheat weedy treatment as compare with wheat weed free treatment.

From the pooled data (2020-21 and 2021-22), it is observed that maximum yield was found in the berseem crop (432.28q/ha) and oats (334.30 q/ha) which was significantly higher as compare with wheat and all tried alternative crops (Table 4.3.4). The minimum yield was found in African seeded crop which was statistically at par with gobhi sarson seeded and transplanted, African sarson seeded and transplanted, lentil and fennel. From the mustard crop, the highest yield was found in raya (14.1q/ha) followed by gobhi sarson transplanted (11.31q/ha). Raya recorded 24.66% more yield as compare to Gobhi sarson transplanted and African transplanted. Gobhi sarsonand African sarson increased seed yield by 28.66% and 12.87% respectively over their direct seeding. Potato-carrot was found at par with potato-radish. The wheat weedy treatment yield was significantly lower as compare with wheat weed free treatment and barley. The wheat weed free treatment was statistically at par with barley. The *Phalaris minor* decreased 52.68 % yield in wheat weedy treatment as compare with wheat weed free treatment. The results are in conformity with those of Banga *et al.,* (1997), Bhan and Kumar (1998) and Singh *et al*.,(2001).

Net income of crop is a collective influence of its yield potential as well as market price. The yield of different crops is variable due to the genetic potential as well as their market price is variable. Transplanted gobhi sarson and African sarson gave more yield than seeded crop due to less weeds in the former practice. The yield of fennel was less but its market price is high than all other tried crops.

Table 4.3.4: Yield of different crops (q/ha) in variable wheat alternative cropping systems

Treatments	Yield of different crops (q/ha)		
	2020-21	**2021-22**	**Pooled data**
Wheat Weedy	32.75	26.30	29.55
Wheat weed free	60.75	64.23	62.45
Gobhi sarson (S)	8.25	9.38	8.78
Gobhi sarson (T)	11.50	11.84	11.67
African sarson (S)	7.00	8.67	7.83
African sarson (T)	9.00	8.13	8.56
Raya	13.25	14.97	14.1
Barley	57.25	57.88	57.50
Berseem	406.75	457.78	432.28
Lentil	12.50	11.21	11.76
Potato-Radish	227.59 (218.79+8.8)	255.41 (247.03+8.38)	241.5 (232.91+8.59)
Potato-Carrot	213.88 (204.78+9.1)	226.92 (218.63+8.29)	220.41 (211.71+8.7)
Oats fodder-seed	316.4 (280+36.4)	352.21 (305.5+46.71)	334.3 (292.75+41.55)
Fennel	9.00	12.05	10.60
CD at 5%	39.19	24.91	16.09

4.3.5 Wheat equivalent yield (q/ha)

The yield of different crops was converted into wheat equivalent yield in order to determine the overall impact of different crops in order to generate comparable yield data. The wheat equivalent yield expresses the total yield (productivity) is being presented in Table 4.3.5 and graphically shown in Fig. 4.1.4. The yield of different crops were multiplied by their MSP or market price and then divided by the MSP of wheat crop. In the first year (2020-21), the maximum wheat equivalent yield was found in potato-carrot (164.84 q/ha). It was significantly higher as compare to the standard treatment of wheat weed free. The second highest yield was found in potato-radish crop rotation (155.78 q/ha) which was statistically at par with potato-radish crop rotation but significantly higher than all other crops. The minimum wheat equivalent yield was found in African sarson seeded (16.7 q/ha) which was significantly lower as compare with potato-radish, potato-carrot barley, lentil and fennel and wheat weed free treatment. The African sarson seeded was statistically at par with African sarson transplanted and gobhi sarson seeded and transplanted. The wheat equivalent yield of all mustard crops was significantly lower as compare with wheat weed free treatment with respect to wheat equivalent yield. The barley crop was statistically at par with fennel crop and wheat weed free treatment. The fennel crop was statistically at par with wheat weed free and berseem with respect to wheat equivalent yield. The oats gave significantly higher wheat equivalent yield as compare with wheat weed free treatment.

In the second year (2021-22), the maximum wheat equivalent yield was found in potato-radish (251.25 q/ha), potato-carrot (249.99 q/ha), oats for fodder and seed (148.75 q/ha), berseem (115.1 q/ha) rotations which were significantly higher than all other crops (Table 4.3.5). The wheat equivalent yield of Potato-carrot was found at par with potato-radish crop rotation. The minimum wheat equivalent yield was found in African sarson transplanted (19.27 q/ha) which was at par with wheat weed free, gobhi sarson seeded and transplanted and lentil. The mustard crops gave significantly lower wheat equivalent yield as compare to wheat weed free and at par with wheat weedy treatment and lentil. Among the mustard, raya gave maximum wheat equivalent yield followed by gobhi sarson transplanted which was 24.63% more. Berseem gave significantly higher wheat equivalent yield as compare with wheat weed free where as fennel wheat equivalent yield was recorded statistically at par with wheat weed free treatment. Oats gave significantly higher wheat equivalent yield as compare with wheat weed free treatment and berseem wheat equivalent yield.

From the pooled data (2020-21 and 2021-22) it can be concluded that, the maximum wheat equivalent yield was found in potato-carrot, potato-radish and oats for seed & fodder which was significantly higher as compare with wheat and wheat alternate crops (Table 4.3.5). Potato-Radish crop rotation was statistically at par with potato- carrot crop rotation with respect to wheat equivalent yield. The minimum wheat equivalent yield was found in African sarson seeded (18.42 q/ha) which was at par with wheat weedy, gobhi sarson seeded and transplanted, African sarson seeded and lentil. All mustard crops gave significantly lower wheat equivalent yield as compare to wheat weed free and these were found at par with wheat weedy treatment and lentil. Among the mustard crops, raya gave maximum wheat equivalent yield followed by gobhi sarson transplanted. The berseem and fennel were found at par with wheat weed free treatment with respect to wheat equivalent yield. The oats gave significantly lower wheat equivalent yield as compare with potato-radish and potato-carrot cropping systems. The results are in conformity with those of Banga *et al.,* (1997), Bhan and Kumar (1998) and Singh *et al.*,(2001).

Wheat equivalent yield was calculated by dividing marketable income of a crop in terms of Rs/ha with the market price of wheat (Rs/q). The crop rotation with highest wheat equivalent yield is considered to be the most economical system. Highest wheat equivalent yield in potato-carrot, potato-radish and oats for fodder and seed may be due to higher yield potential of potato per unit area. Apart from this, the market rates of seeds of carrot, radish and oats are very high which increased wheat equivalent yield as compare to prevalent system of Rice-Wheat. Berseem raised for fodder also significantly improved wheat equivalent yield due to its high yield potential as compared to standard practice of rice-wheat. Due to the high market rate of fennel it also gave wheat equivalent yield comparable to wheat weed free treatment the standard practice. Apart from these rotations barley and raya were also very close to the standard treatment i.e. wheat weed free.

Table 4.3.5: Wheat equivalent yield (q/ha) of different alternate to wheat cropping systems

	Wheat equivalent yield (q/ha)		
Treatments	**2020-21**	**2021-22**	**Pooled**
Wheat weedy	32.80	26.30	29.55
Wheat weed free	60.66	64.23	62.45
Gobhi sarson (S)	21.31	22.08	21.69
Gobhi sarson (T)	25.68	26.55	26.11
African sarson (S)	16.70	20.15	18.42
African sarson (T)	20.40	19.27	19.84
Raya	31.12	35.23	33.18
Barley	46.28	46.89	46.58
Berseem	61.79	115.10	88.48
Lentil	31.764	28.95	30.36
Potato-Radish	155.78	251.24	203.51
Potato-Carrot	164.84	249.99	207.42
Oats fodder and seed	123.34	148.75	136.04
Fennel	51.02	67.15	59.08
CD at 5%	13.97	9.78	12.89

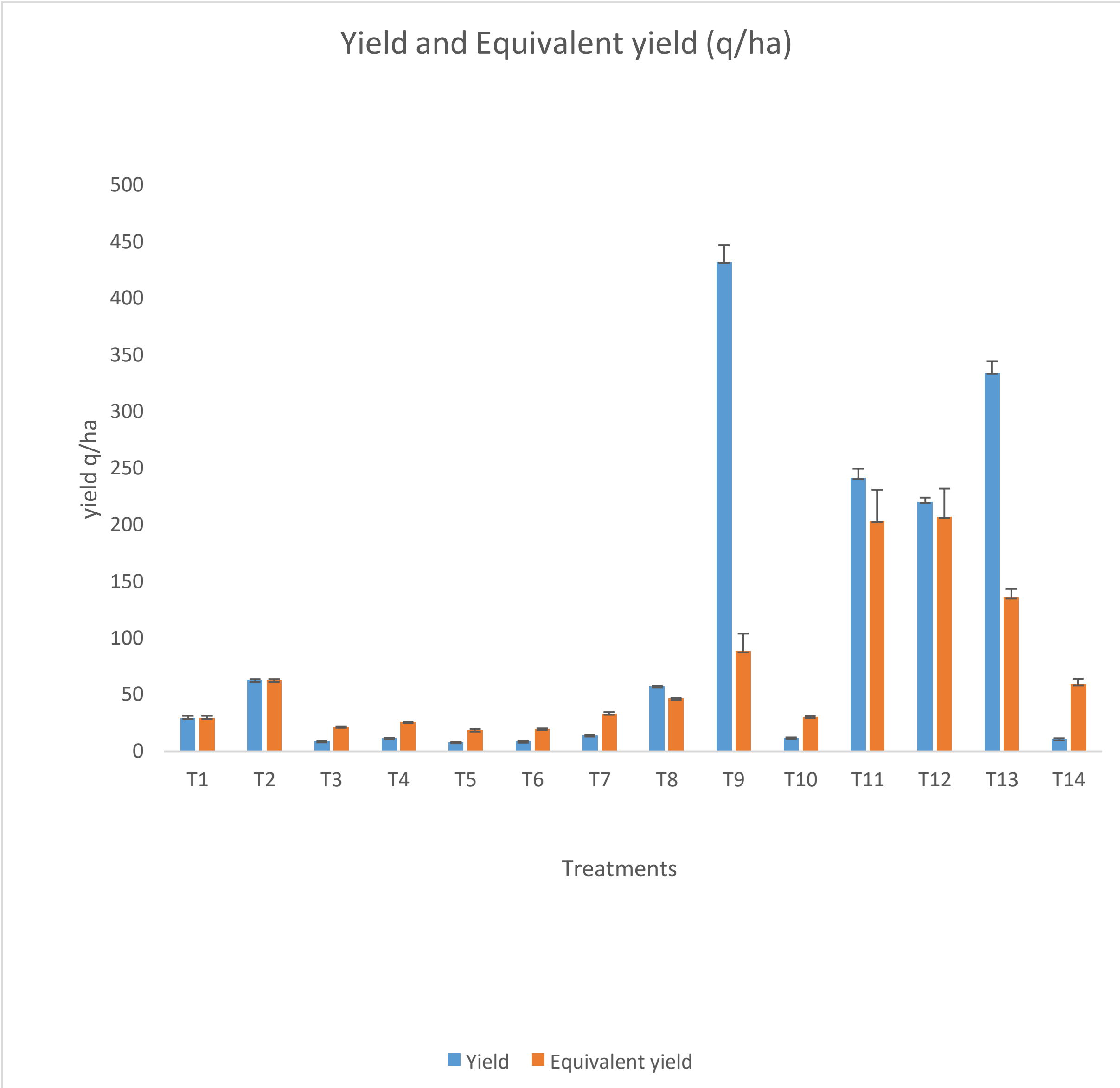


Fig. 4.1.4: Yield and wheat equivalent yield of different crops (q/ha) in variable wheat alternative cropping systems

Note: T1-Wheat weedy, T2-Wheat weed free, T3-Gobhi sarson seeded, T4-Gobhi sarson transplanted, T5-African sarson seeded, T6-African sarson transplanted, T7-Raya, T8-Barley, T9-Berseem, T10-Lentil, T11-Potato-Radish, T12-Potato-Carrot, T13-Oats fodder-seed, T14-Fennel

4.3.6 Straw yield (q/ha)

Straw is major component of total biological yield. Wheat straw yield is very economical which can be used for dry feed of cattle, paper industry and mushroom cultivation etc. The data pertaining to straw yield has been shown in Table 4.3.6. During the first year (2020-21), the maximum straw yield was found in barley (79.85 q/ha) which was significantly higher than all other treatments followed by wheat weed free (76.98 q/ha). The potato-carrot crop rotation was found at par with potato-radish and fennel crop rotation. The oats was significantly higher than wheat weedy crop rotation. From the oil seed crops, significantly maximum straw yield was found in gobhi sarson transplanted (33.25 q/ha) except raya (33.18 q/ha). The African sarson seeded was recorded at par with African sarson transplanted.

During the second year (2021-22), significantly higher straw yield was found in barley (80.60 q/ha) followed by wheat weed free (77.63 q/ha) (Table 4.3.6). The radish was found at par with fennel with respect to straw yield. The oats was significantly higher than wheat weedy crop rotation with respect to straw yield. From the oil seed crops, the raya had significantly maximum straw yield (34.85 q/ha) except gobhi sarson transplanted (34.55 q/ha). The African sarson transplanted (22.38q/ha) gave significantly less straw yield as compare with other oil seed crops.

From the pooled data analysis (2020-21 and 2021-22), the maximum straw yield was found in barley (80.23 q/ha) which was significantly higher than all other treatments followed by wheat weed free (77.30 q/ha) (Table 4.3.6). The carrot was found at par with radish and fennel with respect to straw yield. The oats was significantly higher than wheat weedy crop rotation. From the oil seed crops, the raya had significantly maximum straw yield was found in raya (34.01 q/ha) except gobhi sarson transplanted (33.90 q/ha). The African sarson transplanted gave minimum straw yield as compare with other oil seed crops (23.38q/ha). The African sarson transplanted was recorded at par with African sarson seeded. The straw yield of wheat, barley and oats have high economic value than the straw yield of all other alternative crops.

Table 4.3.6: Straw yield of different crops (q/ha) in variable wheat alternative cropping systems

Treatments	Straw yield (q/ha)		
	2020-21	2021-22	Pooled
Wheat weedy	52.28	50.73	51.50
Wheat weed free	76.98	77.63	77.30
Gobhi sarson (S)	30.88	31.48	31.18
Gobhi sarson (T)	33.25	34.55	33.90
African sarson (S)	24.25	25.05	24.65
African sarson (T)	24.38	22.38	23.38
Raya	33.18	34.85	34.01
Barley	79.85	80.60	80.23
Barseem	0.00	0.00	0.00
Lentil	21.30	18.40	19.85
Potato-Radish	25.51	30.33	27.92
Potato-Carrot	25.03	29.58	27.30
Oats seed	61.51	65.58	63.54
Fennel	26.03	28.13	27.08
CD at 5%	1.59	2.05	1.96

4.3.7 Biological yield (q/ha)

Biological yield is the product of grain yield and straw yield. It depends on many factors, like plant height, spike length, number of grains per spike, number of grains per spike and the number of tiller. The data pertaining to the effect of different treatments on biological yield was given in the Table 4.3.7. During first year (2020-21), significantly higher biological yield was recorded in berseem (406.75 q/ha) as compared with other crop rotations. The lentil was found at par with potato-radish, potato-carrot and fennel. From the oil seed crops, the significantly higher biological yield was found in raya except gobhi sarson transplanted. The minimum biological yield was found in African sarson seeded which was at par with African sarson transplanted.

In the second year (2021-22), the higher biological yield was recorded in berseem (457.78 q/ha). The berseem cropping system was recorded significantly higher as compared with other crop rotations (Table 4.3.7). The biological yield of carrot was found at par with radish and fennel. From the oil seed crops, the higher biological yield was found in raya which was recorded significantly higher than all other oil seed crops except gobhi sarson transplanted. The minimum biological yield was found in African sarson seeded which was at par with African sarson transplanted.

From the analysis of pooled data (2020-21 and 2021-22), it can be concluded that the higher biological yield was found in berseem (432.28 q/ha) which was significantly higher as compared with other crop rotations (Table 4.3.7). The carrot was found at par with radish and fennel. From the oil seed crops, the higher biological yield was found in raya. The raya was found significantly higher than all other oil seed crops except gobhi sarson transplanted. The minimum biological yield was found in African sarson seeded which was at par with African sarson transplanted.

Table 4.3.7: Biological yield of different crops (q/ha) in variable wheat alternative cropping systems

Treatments	Biological yield (q/ha)		
	2020-21	2021-22	Pooled
Wheat weedy	85.1	77.0	81.1
Wheat weed free	137.7	141.9	139.8
Gobhi sarson (S)	39.1	40.9	40.0
Gobhi sarson (T)	44.5	45.9	45.2
African sarson (S)	31.3	33.2	32.3
African sarson (T)	33.4	31.0	32.2
Raya	46.4	49.8	48.1
Barley	137.0	138.5	137.7
Berseem	406.75	457.78	432.28
Lentil	33.6	29.6	31.6
Potato-Radish	33.9	39.1	36.5
Potato-Carrot	33.3	38.7	36.0
Oats seed	108.2	102.0	105.1
Fennel	35.2	40.2	37.7
CD at 5%	5.49	7.30	11.91

4.3.8 Harvest index

Harvest index is an one of important parameter indicating the efficiency of partitioning of dry matter to the economic parts of the crop.

Harvest index can be calculated as

$$\text{Harvest index (\% age)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

The data pertaining to the effect of different treatments on harvesting index was given in the Table 4.3.8. During the first year (2020-21), the maximum harvest index was found in wheat weed free (44.1) followed by oats (43.0). The least harvest index was found in gobhi sarson seeded (20.8). From the oil seed crops, the maximum harvest index was found in raya. The barley had better harvest index than wheat weedy.

In the second year (2021-22), the maximum harvest index was found in wheat weed free (45.2) followed by barley (41.4) (Table 4.3.8). The least harvest index was found in gobhi sarson seeded (22.6). From the oil seed crops, the maximum harvest index was found in raya. The oats had better harvest index than wheat weedy.

From the pool data analysis (2020-21 and 2021-22), it can be concluded that the maximum harvest index was found in wheat weed free (44.6) followed by barley (41.4) (Table 4.3.8). The least harvest index was found in gobhi sarson seeded (21.8). From the oil seed crops, the maximum harvest index was found in raya. The oats had better harvest index than wheat weedy.

Table 4.3.8. Harvest index (% age) of different crops in variable wheat alternative cropping systems

Treatments	Harvest Index (% age)		
	2020-21	2021-22	Pooled
Wheat weedy	38.5	33.8	36.2
Wheat weed free	44.1	45.2	44.6
Gobhi sarson (S)	20.8	22.6	21.8
Gobhi sarson (T)	25.2	24.7	24.9
African sarson (S)	22.6	24.5	23.5
African sarson (T)	27.0	27.7	27.4
Raya	28.0	29.8	28.9
Barley	41.3	41.4	41.4
Berseem	0.0	0.0	0.0
Lentil	36.1	37.4	36.8
Potato-Radish	24.7	22.9	23.7
Potato-Carrot	24.8	23.6	24.2
Oats fodder & seed	43.0	35.5	39.2
Fennel	25.9	29.7	27.8

4.3.9 Soil seed bank

Soil seed bank consists of both recent and seed shed of previous years in the field which determine the population pressure of *P minor* in the coming years. The soil seed bank of *Phalaris minor* was determined at the time of termination of experiment i.e. end of April 2022. The soil was collected from the central portion of the plot (0-15 cm top depth) with one square feet quadrant from two spots per experimental plot. Seeds of *Phalaris minor* were separated by washing the soil with water in a sieve and counting was done. Later on seeds were converted to per sq.m. basis for reporting. The data on soil seed bank under different cropping systems, described in Table 4.3.9 and graphically shown in Fig. 4.1.5. Results showed that the maximum seed number was found in wheat weedy (585.5) which was significantly higher as compare to all other alternative to wheat cropping systems. The minimum number of seeds (zero) was found in wheat weed free and it was found at par with berseem, potato-radish, potato-carrot and oats fodder and seed systems. From the mustard crop, the maximum number of seeds of *P.minor* were found in African sarson seeded (288.6) which were significantly more than African sarson transplanted, gobhi sarson seeded and transplanted and raya. The transplanting of gobhi sarson and African sarson had more number of *Phalaris minor* seeds in soil as compare to direct seeding. The gobhi sarson seeded had 28.33% more seeds than gobhi sarson transplanted. Similarly African sarson seeded had 18.18% more number of seeds than African sarson transplanted. The lentil had significantly more number of seeds than mustard but significantly lower than barley and wheat weedy. The fennel had 10% more number of seeds of *Phalaris minor* than wheat weed free where as it had significantly less number of seeds as compare to gobhi sarson and African sarson both seeded and transplanted. The objective of this study was to find out cultural control of *Phalaris minor* by replacing wheat with other *Rabi* season crops.

Continuous sowing of berseem, oats and potato based cropping systems for at least two years after rice have completely eliminated *Phalaris minor* seed production and all these wheat alternate crops were found at par with the standard practice of rice-wheat (*Phalaris minor* free). In fodder crops (berseem and oats), the vegetatively growing *Phalaris minor* plants were cut along with each cutting resulting in no addition of Phalaris minor seeds in soil seed bank during first year and during second year only few seeds lying in deeper soil layers will germinate which will not be allowed to produced seed. Similarly in potato based rotations, growing *Phalaris minor* plants (in only vegetative stage) will be uprooted during earthing up and with digging up operations resulting in no addition of *Phalaris minor* seed bank during first year. During second year only few weed seeds lying in deeper soil layers will germinate and these will not be allowed to produce seeds as these are also uprooted during earthing up and uprooting operations of potato. All these above practices were found significantly superior for controlling *Phalaris minor* than other alternate crops like gobhi sarson, African sarson, raya, barley, lentil and fennel. The results are in conformity with those of Banga *et al.,* (1997), Bhan and Kumar (1998), Dorado *et at* (1999), Hassanein *et al.,* (1999), Barberi and Casio (2001) and Singh *et al*.,(2001). Similar type recommendations was given by Punjab Agriculture University Ludhiana (Punjab) in the package of practices in the *Rabi* season regarding cultural control of *Phalaris minor* in wheat (Anonymous 2018-19).

Table 4.3.9: Soil seed bank status of *Phalaris minor* seeds at the time of termination of experiment (after two years)

Treatments	Soil seed bank (0-15 cm soil depth of one sq.m.)
Wheat weedy	585.5
Wheat weed free	0
Gobhi sarson (S)	213.7
Gobhi sarson (T)	166.5
African sarson (S)	288.6
African sarson (T)	244.2
Raya	130.4
Barley	446.8
Berseem	0
Lentil	341.3
Potato-Radish	0
Potato-Carrot	0
Oats fodder and seed	0
Fennel	111.0
CD at 5%	36.7

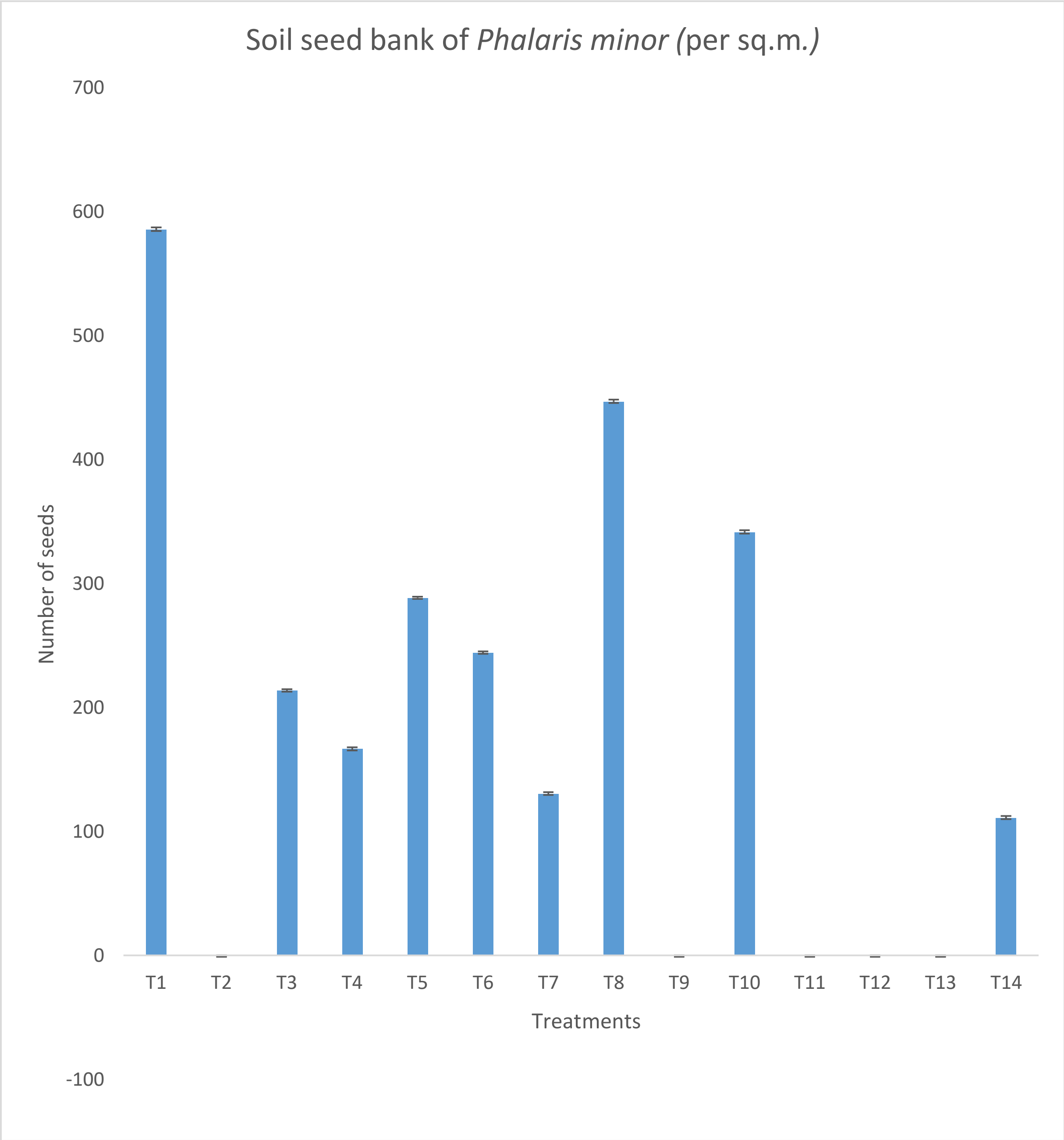


Fig. 4.1.5: Soil seed bank status of *Phalaris minor* (per sq.m.) seeds at the time of termination of experiment

Note: T1-Wheat weedy, T2-Wheat weed free, T3-Gobhi sarson seeded, T4-Gobhi sarson transplanted, T5-African sarson seeded, T6-African sarson transplanted, T7-Raya, T8-Barley, T9-Berseem, T10-Lentil, T11-Potato-Radish, T12-Potato-Carrot, T13-Oats fodder-seed, T14-Fennel

4.4 Net profit (Rs./ha)

The net profit of wheat and alternate to wheat *Rabi* crops was calculated on the basis of return over variable cost and wheat equivalent yield. By using the prevailing costs of input and market rate of the produce, return over variable cost was substracted from gross income. The data related to the net profit has been shown in Table 4.4 which was calculated on the basis of pooled data. It can be concluded from the pooled data analysis (2020-21 and 2021-22) that the maximum gross income was found in potato-carrot (Rs.409642/ha) followed potato-radish crop rotation (Rs.401931/ha) (Table 4.4). The minimum gross income was found in African sarson transplanted (Rs.36641/ha). The maximum cost of cultivation was found in potato-carrot (Rs.95993/ha) followed potato-radish crop rotation (Rs. 94463/ha). The minimum cost of cultivation was found in fennel (Rs.27405/ha). The maximum net profit was found in potato-carrot crop rotation (Rs.313650/ha) followed by potato-radish crop rotation (Rs.307468.3). Oats as fodder and seed gave net profit of Rs.229317/ha and berseem of Rs.132882/ha which was higher as compared with traditional practice of growing wheat. The minimum net profit was found in African sarson transplanted (Rs.8778/ha). Both the mustard crops (seeded and transplanted) gave lower net profit than wheat crop. The other crops like barley and lentil also gave lower net profit as compared with wheat weed free. The higher B:C was found in oats fooder and seed (5.83) followed by potato based crop rotations. The lower B:C was found in African sarson transplanted.

Highest net profit was observed in potato-carrot, potato-radish and oats for fodder and seed may be due to higher wheat equivalent yield in these rotations. The potato and oats had more yield (tuber and seed) as well as wheat equivalent yield as compared with other crop rotations. Apart from higher yield of potato, the market rates of seeds of carrot, radish and oats are very high which increased net profit as compare to rice-wheat crop rotation. Mustard gave minimum net profit both under weedy and weed free conditions as compare to wheat as it had less yield and low market rates.

Table 4.4: Gross income, Expenditure and Net profit (Rs./ha) of different crops in variable wheat alternative cropping systems

Treatments	Gross income (Rs./ha)	Expenditure (Rs./ha)	Net profit (Rs./ha)	B:C
Wheat weedy	58361	33541	24820	0.74
Wheat weed free	123339	46201	77138	1.67
Gobhi sarson (S)	42844	28088	14756	0.53
Gobhi sarson (T)	51574	28088	23487	0.84
African sarson (S)	38928	27863	11066	0.40
African sarson (T)	36641	27863	8778	0.32
Raya	65526	27938	37589	1.35
Barley	92000	31491	60510	1.92
Berseem	174683	41800	132883	3.18
Lentil	59953	34038	25915	0.76
Potato-Radish	401931	94463	307468	3.25
Potato-Carrot	409642	95993	313650	3.27
Oats fodder & seed	268679	39363	229316	5.83
Fennel	116692	27405	89287	3.26

Note: Net profit was calculated on the basis of wheat equivalent yield

Experiment 2: Smothering potential of different intercrops on *Phalaris minor* in bed planting technology of wheat sowing.

4.1 Weed density

4.1.1 Count of *Phalaris minor* per sq.m.

The infestation of weeds especially *Phalaris minor* had direct influence on the yield of wheat crop. The count of *Phalaris minor* was monitored at different intervals to evaluate the smothering potential of different intercrops sown in the furrow of bed planted wheat. Due to large variation in *Phalaris minor* count, the data was subjected to square root transformation. The data was analyzed after adding one to original values and by taking the under root. The weed data was recorded only for *Phalaris minor* the target weed. The count of *Phalaris minor* was reported on sq.m basis. The count of *Phalaris minor* was observed at 30, 60, 90 DAS and at harvest as shown in Table 4.1.1-a and 4.1.1-b and graphically shown in Fig.4.1.1. The results are being discussed on the basis of transformed not original values. In the first year (2020-21) at 30 DAS, it was observed that maximum count of *Phalaris minor* was found in wheat weedy cropping system (5.41 per sq.m.) which was significantly more than weedy check of all treated crops. Intercropping of wheat with lentil weedy (4.97 per sq.m.) with wheat recorded significantly more *Phalaris minor* count than other intercrops. The intercropping of lentil weedy recorded significantly higher *P. minor* count than all other cropping system except wheat weedy cropping system. Among the weedy cropping systems, the lower count of *Phalaris minor* was found in intercropping of wheat with gobhi sarson cropping system (4.44 per sq.m.) which was significantly lower than all weedy cropping systems of African sarson, lentil, fenugreek and dil seed. The intercropping of wheat with spices crops like fenugreek, fennel and dil seed recorded statistically at par count of *P.minor* per sq.m.

In the second year (2021-22) at 30 DAS, significantly maximum count of *Phalaris minor* was found in wheat weedy cropping system (5.85 per sq.m.) (Table 4.1.1-a). Among the weedy intercropping systems, the minimum count of *P. minor* was found in intercropping of wheat with gobhi sarson (3.52 per sq.m.) which was significantly more than all intercropping systems except fennel and dil seed. The intercropping of wheat with gobhi sarson weedy recorded significantly less count of *Phalaris minor* than all other cropping system. The intercropping of wheat with dil seed was found at par with intercropping of wheat with African sarson, gobhi sarson and fenugreek with respect to count of *Phalaris minor*.

From the pooled data (2020-21 and 2021-22) it is clear that, significantly maximum count of *P. minor* recorded at 30 DAS was found in wheat weedy cropping system (5.63 per sq.m (Table 4.1.1-a). Among the weedy cropping systems, the minimum count of *P. minor* was found in intercropping of wheat with gobhi sarson cropping system (3.98 per sq.m). The intercropping of wheat with gobhi sarson weedy recorded significantly less count of *P.minor* than all other cropping system except wheat with fennel intercropping system. The intercropping of wheat with fenugreek was found at par with intercropping of wheat with African sarson, dil seed and lentil weedy cropping system.

In the first year (2020-21) at 60 DAS, it was found that significantly maximum count of *Phalaris minor* was found in wheat weedy intercropping system (6.44 per sq.m.) (Table 4.1.1-a). Among the weedy cropping systems, the lower count of *P.minor* was found in intercropping of wheat with fennel cropping system (4.74 per sq.m.) which was found at par to intercropping of wheat with all other crops like gobhi sarson, African sarson, lentil, fenugreek and dil seed grown under weedy conditions.

In the second year (2021-22) at 60 DAS, significantly higher count of *Phalaris minor* was found in wheat weedy cropping system (6.76 per sq.m.) than all other intercropping systems (Table 4.1.1-a). The intercropping of wheat with lentil weedy cropping system was found at par with intercropping of wheat with African sarson weedy cropping system. Among the weedy intercropping systems, the minimum count of *P. minor* was found in intercropping of wheat with fennel cropping system (4.55 per sq.m.). It was found that count of *Phalaris minor* was 32.69% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system. It was also found that intercropping of wheat with fennel was at par with intercropping of wheat with gobhi sarson, dil seed and fenugreek weedy cropping system. The intercropping of wheat with African sarson weedy and intercropping of wheat with lentil weedy cropping system were found at par.

From the pooled data (2020-21 and 2021-22) it was found that significantly higher count of *Phalaris minor* was found in wheat weedy cropping system (6.76 per sq.m.) (Table 4.1.1-a). The intercropping of wheat with lentil weedy recorded significantly higher *Phalaris minor* count than all other cropping systems except fenugreek and African sarson. Among the weedy intercropping systems, the lower count of *Phalaris minor* was found in intercropping of wheat with fennel (4.65 per sq. m.). It was found that count of *Phalaris minor* was 31.21% less in intercropping of wheat with fennel weedy as compared to wheat weedy intercropping system. It was significantly lower than all weedy intercropping systems and found at par with intercropping of wheat with dill seed weedy intercropping system. The intercropping of wheat with African sarson weedy was found at par with intercropping of wheat with lentil weedy cropping system.

In the first year (2020-21) at 90 DAS, it was noticed that maximum count of *Phalaris minor* was found in wheat weedy (8.14 per sq.m.) which was significantly higher than all other intercropping systems (Table 4.1.1-b). The intercropping of wheat with lentil weedy gave significantly higher count of *P.minor* than all other cropping systems. Among the weedy intercropping systems, the least count of *Phalaris minor* was found in intercropping of wheat with fennel (5.70 per sq.m.). It was found that count of *Phalaris minor* was 29.97% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system showing more smothering effects of fennel than wheat. It was found wheat fennel intercropping system recorded significantly less count of *P. minor* than all other intercropping systems except dil seed.

In the second year (2021-22) at 90 DAS, maximum count of *Phalaris minor* was found in wheat weedy cropping system (8.51 per sq.m.) which was significantly higher than all other intercropping systems (Table 4.1.1-b). It was observed that count of *P.minor* in intercropping systems with wheat, lentil weedy intercropping system recorded significantly higher count than other systems. Among the weedy intercropping systems, significantly less count of *Phalaris minor* was found in intercropping of wheat with fennel (5.43 per sq.m.) than all other intercropping systems. It was found that count of *Phalaris minor* was 36.19 % less in intercropping of wheat with fennel weedy as compared to wheat weedy intercropping system. It was also found that intercropping of wheat with fennel weedy cropping system recorded significantly lower count of *P.minor* than all other weedy cropping systems except intercropping of dil seed. The intercropping of wheat with fenugreek was found at par with intercropping of wheat with African sarson weedy cropping system.

In the pooled data (2020-21 and 2021-22) at 90 DAS, wheat weedy significantly showed higher count of *Phalaris minor* (8.33 sq.m) (Table 4.1.1-b). The intercropping of wheat with lentil weedy recorded significantly higher than all other intercropping system except wheat weedy cropping system. Among the weedy intercropping systems, the lower count of *P. minor* was found in intercropping of wheat with fennel (5.56 per sq.m.).

Table 4.1.1-a: Periodic count of *Phalaris minor* (per sq.m) as influenced by different intercrops grown in bed planted wheat

Treatments	Count of *Phalaris minor* per sq.m					
	30DAS			60DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat, weedy	5.41 (28.3)	5.85 (33.3)	5.63 (30.8)	6.44 (40.5)	6.76 (44.8)	6.60 (42.6)
Wheat+Gobhi sarson, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Gobhi sarson, weedy	4.44 (18.8)	3.52 (11.5)	3.98 (15.1)	4.79 (22)	4.76 (21.8)	4.77 (21.9)
Wheat+African sarson, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+African sarson, weedy	4.74 (21.5)	4.58 (20.8)	4.66 (21.1)	4.84 (23.3)	5.00 (24)	4.92 (23.6)
Wheat+Lentil, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Lentil, weedy	4.97 (23.8)	4.66 (18.3)	4.81 (21)	4.99 (23.9)	5.07 (24.3)	5.03 (24.1)
Wheat+Fenugreek, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fenugreek, weedy	4.71 (21.3)	4.38 (18.2)	4.55 (19.7)	4.82 (22.2)	4.79 (22)	4.80 (22.1)
Wheat+Fennel, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fennel, weedy	4.55 (19.8)	3.83 (13.8)	4.19 (16.8)	4.74 (21.5)	4.55 (19.8)	4.65 (20.6)
Wheat+Dilseed, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Dilseed, weedy	4.63 (20.5)	4.33 (17.8)	4.48 (19.1)	4.76 (21.8)	4.68 (21)	4.72 (21.4)
CD at 5%	0.21	0.28	0.29	0.27	0.24	0.09

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values √x+1

It was found that count of *Phalaris minor* was 33.25% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system and it was significantly lower than all weedy cropping systems and found at par with intercropping of wheat with dill seed weedy cropping system. The intercropping of wheat with gobhi sarson weedy was found at par with intercropping of wheat with fenugreek weedy intercropping system.

In the first year (2020-21) at harvest, it had been found that maximum count of *Phalaris minor* was found in wheat weedy (7.75 per sq.m.) (Table 4.1.1-b). The intercropping of wheat with lentil weedy recorded significantly higher number of *Phalaris minor* plants than all other intercropping system except wheat weedy cropping system and it was at par with intercropping of wheat with African sarson weedy intercropping system. Among the weedy intercropping systems, the low count of *Phalaris minor* was found in intercropping of wheat with fennel (5.41 per sq.m.). It was found that count of *Phalaris minor* was 30.19% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system and also wheat intercropped with fennel gave significantly less count of *P.minor* except dil seed. The intercropping of wheat with gobhi sarson weedy was found at par with intercropping of wheat with fenugreek weedy cropping system.

In the second year (2021-22) at harvest, maximum count of *Phalaris minor* was found in wheat weedy (7.84 per sq.m.) (Table 4.1.1-b). From all weedy intercropping systems with wheat, significantly higher count was observed in lentil weedy intercropping system. Among the weedy cropping systems, the least count of *Phalaris minor* was found in intercropping of wheat with fennel cropping system (4.82 per sq.m.). It was found that count of *Phalaris minor* was 38.52 % less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system and this system was found at par with intercropping of wheat with dil seed weedy cropping system and significantly lower than all other weedy cropping systems. The intercropping of wheat with fenugreek was found at par with intercropping of wheat with African sarson weedy cropping system.

In the pooled data (2020-21 and 2021-22) at harvest, maximum count of *Phalaris minor* was found in wheat weedy intercropping system (7.79 per sq.m.) which was significantly higher than all other intercropping systems (Table 4.1.1-b). The intercropping of wheat with lentil weedy recorded significantly higher count of *P.minor* per sq.m. than all other intercropping systems except wheat weedy cropping system and at par with intercropping of wheat with African sarson weedy intercropping system. Among the weedy intercropping systems, the lower count of *Phalaris minor* was found in intercropping of wheat with fennel cropping system (5.11 per sq.m.). It was found that count of *Phalaris minor* was 34.40% less in intercropping of wheat with fennel weedy as compared to wheat weedy intercropping system and it gave significantly lower count of *P.minor* (per sq.m.) than all weedy intercropping systems and found at par with intercropping of wheat with dill seed weedy cropping system. The intercropping of wheat with gobhi sarson weedy was found at par with intercropping of wheat with fenugreek weedy cropping system. Similar reports were given by Wasaya *et al*.,(2013).

Among all intercrops, the smothering potential of fennel and dil seed was comparatively more than other tried crops. Also gobhi sarson showed more smothering potential due to its wider leaves than African sarson when observations were recorded at all periodic intervals. Reduction in the count of *Phalaris minor* in medicinal cropping system (fennel, dil seed and fenugreek) might be due to release of volatile compounds by these crops which reduced the count of *Phalaris minor*. Also fennel and dil seed due to their quick growth and wider leaves provided more smothering effect on *Phalaris minor* than other crops.

Table 4.1.1-b: Periodic count of *Phalaris minor* (per sq.m) as influenced by different intercrops grown in bed planted wheat

Treatments	Count of *Phalaris minor* per sq.m					
	90DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat, weedy	8.14 (65.3)	8.51 (71.5)	8.33 (68.4)	7.75 (59)	7.84 (60.5)	7.79 (59.8)
Wheat+Gobhi sarson, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Gobhi sarson, weedy	5.91 (34)	5.84 (32.3)	5.88 (33.1)	5.72 (31.8)	5.41 (28.3)	5.56 (30)
Wheat+African sarson, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+African sarson, weedy	6.69 (43.8)	6.08 (36)	6.38 (39.9)	6.56 (42)	5.61 (30.5)	6.08 (36.3)
Wheat+Lentil, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Lentil, weedy	6.93 (47)	6.42 (40.3)	6.67 (43.6)	6.69 (43.8)	6.02 (35.3)	6.35 (39.5)
Wheat+Fenugreek, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fenugreek, weedy	6.20 (37.5)	5.89 (33.8)	6.05 (35.6)	5.87 (33.5)	5.50 (29.3)	5.69 (31.4)
Wheat+Fennel, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fennel, weedy	5.70 (31.5)	5.43 (28.5)	5.56 (30)	5.41 (28.3)	4.82 (22.3)	5.11 (25.3)
Wheat+Dilseed, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Dilseed, weedy	5.85 (33.3)	5.59 (30.3)	5.72 (31.8)	5.54 (29.8)	4.92 (23.3)	5.23 (26.5)
CD at 5%	0.20	0.25	0.21	0.17	0.18	0.29

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values √x+1

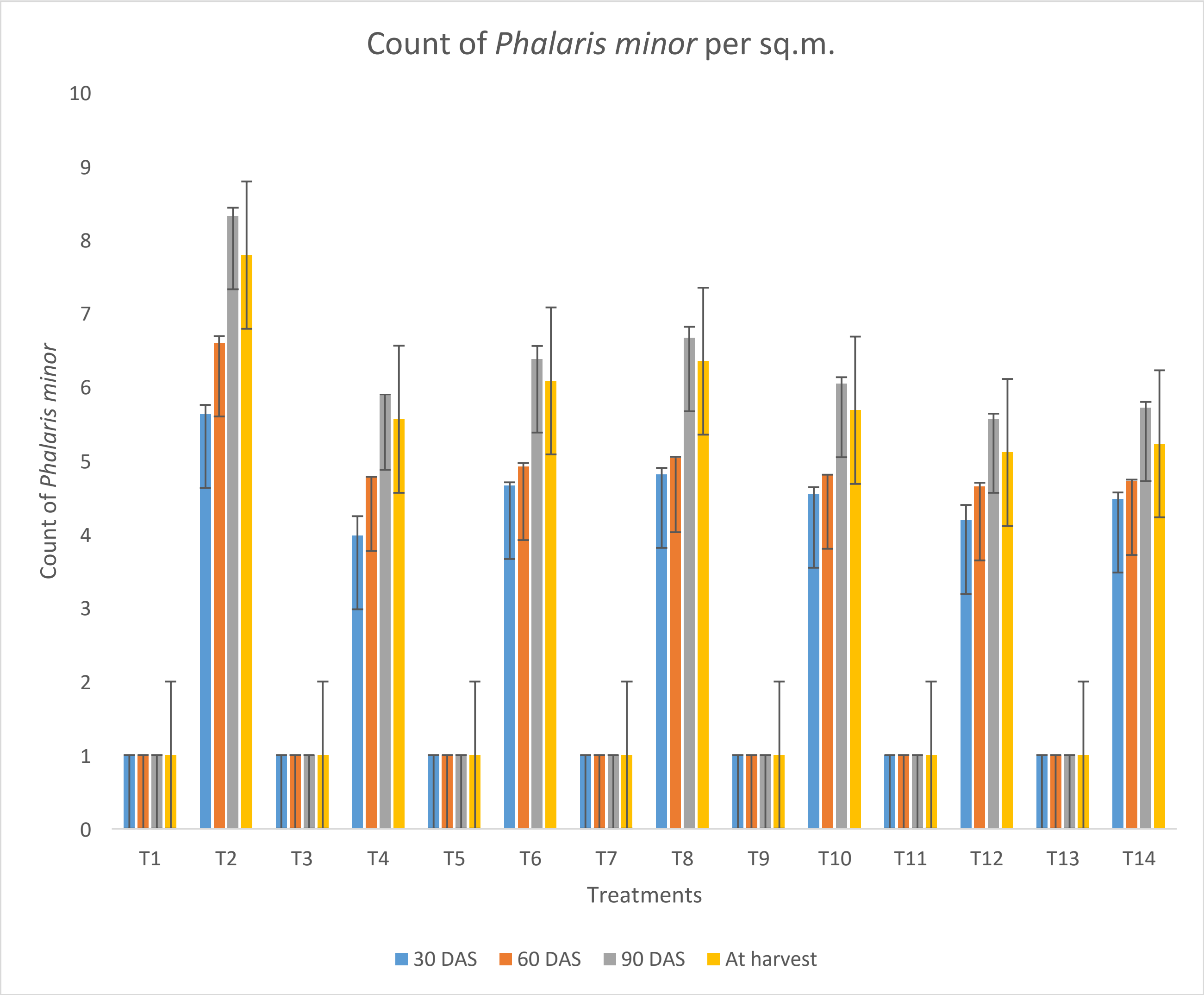


Fig. 4.1.1: Periodic count of *Phalaris minor* (per sq.m) as influenced by different intercrops grown in bed planted wheat

Note: T1-Wheat weed free, T2-Wheat weedy. T3-Wheat+Gobhi sarson weed free, T4-Wheat+Gobhi sarson weedy, T5-Wheat+African sarson weed free, T6-Wheat+African sarson weedy, T7-Wheat+Lentil weed free, T8-Wheat+Lentil weedy, T9-Wheat+Fenugreek weed free, T10-Wheat+Fenugreek weedy, T11-Wheat+Fennel weed free, T12-Wheat+Fennel weedy, T13-Wheat+Dil seed weed free, T14-Wheat+dil seed weedy

4.1.2 Dry matter accumulation by *Phalaris minor* (q/ha)

Dry matter of *Phalaris minor* indicates the extent of competing ability of *Phalaris minor* with crops and it is the most reliable parameter than weed count for determining loss of yield due to weed competition. More the dry matter of weeds, more will be the crop losses. Due to large variations in the data for dry matter accumulation by weeds, it was subjected to square root transformation like weed count. The results are discussed on the basis of transformed valus not the original ones. Dry matter of *Phalaris minor* was noted periodically at 30, 60, 90 DAS and at harvest as shown in Table 4.1.2-a and 4.1.2-b and graphically shown in Fig.4.1.2. During the first year at 30 DAS, it had been found that significantly higher dry matter of *Phalaris minor* was found in wheat weedy intercropping system (3.04 q/ha) (Table 4.1.2-a). Among all intercropping systems, the wheat and lentil intercropping system showed significantly higher dry matter of *P.minor* except intercropping of wheat with African sarson weedy. Among the weedy intercropping systems, the lower dry matter of *Phalaris minor* was found in intercropping of wheat with gobhi sarson cropping system (2.30 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with intercropping of wheat with fennel (2.36 q/ha). The intercropping of wheat with dil seed weedy was found at par with intercropping of wheat with fenugreek weedy.

In the second year (2021-22) at 30 DAS, wheat weedy gave significantly higher dry matter of *Phalaris minor* (3.12 q/ha) (Table 4.1.2-a). The wheat weedy cropping system had significantly higher dry matter of *P.minor* than all other cropping systems. The intercropping of wheat with lentil weedy gave significantly higher dry matter of *Phalaris minor* than all other intercropping systems. Among the weedy cropping systems, the least dry matter of *Phalaris minor* was found in intercropping of wheat with gobhi sarson (2.20 q/ha) which was found at par with intercropping of wheat with fennel (2.21q/ha). The intercropping of wheat with dil seed weedy was found at par with intercropping of wheat with African sarson weedy and intercropping of wheat with fenugreek weedy cropping system.

In the pooled data (2020-21 and 21-22) at 30 DAS, significantly maximum dry matter of *Phalaris minor* was found in wheat weedy cropping system (3.08 q/ha) (Table 4.1.2-a). From diferent intercropping system along with wheat, lentil weedy gave significantly higher dry matter of *Phalaris minor*. Among the weedy intercropping systems, the least dry matter of *P.minor* was found in intercropping of wheat with gobhi sarson (2.25 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with intercropping of wheat with fennel weedy (2.28 q/ha). The intercropping of wheat with dil seed weedy was found at par with intercropping of wheat with African sarson weedy and intercropping of wheat with fenugreek weedy cropping system.

During 2020-21 at 60 DAS, it had been found that maximum dry matter of *Phalaris minor* was found in wheat weedy intercropping system (5.14 q/ha) which was significantly higher than all other intercropping systems (Table 4.1.2-a). The intercropping of wheat with lentil weedy gave significantly higher dry matter of *P.minor* than all other intercropping systems. Among the weedy intercropping systems, the minimum dry matter of *Phalaris minor* was found in intercropping of wheat with fennel cropping system (3.64 q/ha). It was found that dry matter of *Phalaris minor* was 29.18 % less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system which was lower than all weedy intercropping systems. The intercropping of wheat with gobhi sarson weedy was found at par with intercropping of wheat with fenugreek weedy cropping system.

In the second year (2021-22) at 60 DAS, maximum dry matter of *Phalaris minor* was found in wheat weedy cropping system (5.24 q/ha) which was significantly higher than all other intercropping systems (Table 4.1.2-a). Among weedy intercropping systems, significantly higher dry matter of *P.minor* was observed in intercropping of wheat with lentil weedy intercropping system. Among the weedy intercropping systems, the least dry matter of *Phalaris minor* was found in intercropping of wheat with fennel (3.50 q/ha) which was significantly lower than all weedy cropping systems. It was found that dry matter of *Phalaris minor* was 33.2% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system. The intercropping of wheat with dil seed weedy was found at par with intercropping of wheat with African sarson weedy and intercropping of wheat with gobhi sarson weedy cropping system.

In the pooled data (2020-21 and 21-22) recorded 60 DAS, maximum dry matter of *Phalaris minor* was found in wheat weedy cropping system (5.19 q/ha) which was significantly higher than all other intercropping systems (Table 4.1.2-a). The intercropping of wheat with lentil weedy recorded significantly higher dry matter accumulation by *P. minor* than all other cropping systems. Among the weedy cropping systems, least dry matter of *Phalaris minor* was observed in intercropping of wheat with fennel (3.57q/ha) which was 31.21% less as compared to wheat weedy intercropping system. Dry matter of *P.minor* in fennel intercropping system was significantly lower than all weedy cropping systems. The intercropping of wheat with dil seed weedy was found at par with intercropping of wheat with gobhi sarson weedy cropping system. The intercropping of wheat with fenugreek weedy was found at par with intercropping of wheat with African sarson weedy cropping system.

Intercropping of fennel significantly reduced dry matter of *Phalaris minor* than all other tried intercrops indicating its more smothering potential. Dil seed crop showed good smothering crop next to fennel. Lentil and fenugreek were found poor smothering crops due to their short stature as dry matter of *Phalaris minor* was more in these crops. Among oil seed crops, gobhi sarson showed more smothering potential on *Phalaris minor* than African sarson.

In the first year (2020-21) at 90 DAS, it had been found that maximum dry matter of *Phalaris minor* was found in wheat weedy cropping system (6.08 q/ha) which was significantly higher than all other intercropping systems (Table 4.1.2-b). From the weedy intercropping, the significantly higher dry matter of *P.minor* was found in lentil weedy. Among the weedy cropping systems, fennel cropping system gave significantly least dry matter of *Phalaris minor* (4.22 q/ha) than all other intercrops. It was found that dry matter of *Phalaris minor* was 30.59% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system. Intercropping of fennel produced significantly less weed dry matter than all weedy cropping systems. Intercropping of wheat with gobhi sarson weedy was found at par with intercropping of wheat with dil seed weedy and both these intercropping systems recorded significantly less dry matter of *Phalaris minor* than all other intercropping systems except fennel.

In the second year (2021-22) at 90 DAS, significantly higher dry matter of *Phalaris minor* was found in wheat weedy cropping system (6.15 q.ha) (Table 4.1.2-b). From weedy intercropping, lentil weedy cropping system was noted significantly higher *P.minor*. Among the weedy cropping systems, the least dry matter of *P.minor* found in intercropping of wheat with fennel (4.09 q/ha). It was found that dry matter of *Phalaris minor* was 33.49 % less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system. Intercropping of fennel in wheat was found at par with dil seed weedy intercropping system The intercropping of wheat with dil seed was found at par with intercropping of wheat with gobhi sarson weedy cropping system.

Table 4.1.2-a: Periodic dry matter of *Phalaris minor* (q/ha) in different intercrops grown in bed planted wheat

Treatments	Dry matter of *Phalaris minor* (q/ha)					
	30DAS			60DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	1.00 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat, Weedy	3.04 (8.3)	3.12 (8.8)	3.08 (5.5)	5.14 (25.5)	5.24 (26.4)	5.19 (26.0)
Wheat+Gobhi sarson, weed free	1.00 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Gobhi sarson, weedy	2.30 (4.3)	2.20 (3.8)	2.25 (4.1)	3.86 (13.9)	3.73 (13.0)	3.80 (13.4)
Wheat+African sarson, weed free	1.00 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+African sarson, weedy	2.52 (5.4)	2.40 (4.8)	2.46 (5.1)	4.16 (16.3)	3.83 (13.7)	3.99 (15)
Wheat+Lentil, weed free	1.00 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Lentil, Weedy	2.63 (5.9)	2.60 (5.8)	2.61 (5.9)	4.32 (17.7)	4.31 (17.6)	4.32 (17.7)
Wheat+Fenugreek, weed free	1.00 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fenugreek, weedy	2.49 (5.2)	2.38 (4.7)	2.43 (4.9)	3.99 (14.9)	3.81 (13.5)	3.90 (14.2)
Wheat+Fennel, weed free	1.00 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fennel, Weedy	2.36 (4.6)	2.21 (3.9)	2.28 (4.2)	3.64 (12.3)	3.50 (11.3)	3.57 (11.8)
Wheat+Dilseed, weed free	1.00 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Dilseed, Weedy	2.47 (5.1)	2.35 (4.5)	2.41 (4.8)	3.85 (13.8)	3.72 (12.9)	3.79 (13.4)
CD at 5%	0.12	0.13	0.06	0.07	0.13	0.10

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values $\sqrt{x+1}$

From the pooled data (2020-21 and 2021-22) at 90 DAS, significantly maximum dry matter of *Phalaris minor* was found in wheat weedy cropping system (6.11 q/ha) (Table 4.1.2-b). The intercropping of wheat with lentil weedy gave significantly higher dry matter of *Phalaris minor*. Among the weedy cropping systems, the least dry matter of *P.minor* was found in intercropping of wheat with fennel cropping system (4.15 q/ha). It was found that dry matter of *P.minor* was 30.07% less in fennel weedy as compared to wheat weedy cropping system which was significantly lower than all weedy cropping systems. The intercropping of wheat with dil seed was found at par with intercropping of wheat with gobhi sarson weedy cropping system.

During first year (2020-21) at the time of harvest, it had been found that wheat weedy cropping system showed significantly higher dry matter of *Phalaris minor* (5.67 q/ha) (Table 4.1.2-b). The intercropping of wheat with lentil weedy showed significantly higher dry matter of *Phalaris minor* and was at par with intercropping of wheat with African sarson weedy intercropping system. Among the weedy cropping systems, least dry matter of *Phalaris minor* was found in intercropping of wheat with fennel cropping system (3.60 q/ha). It was found that dry matter of *Phalaris minor* was 35.50% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system. It was also found that dry matter of *Phalaris minor* was significantly lower than all weedy cropping systems and at par with intercropping of wheat with dil seed weedy. Gobhi sarson intercropping significantly reduced dry matter of *Phalaris minor* than African sarson.

In the second year (2021-22) at harvest, wheat weedy gave significantly higher dry matter of *Phalaris minor* (5.86 q/ha) (Table 4.1.2-b). From weedy intercropping systems, lentil weedy intercropping system recorded significantly higher DM of *Phalaris minor*. Among the weedy intercropping systems, the least dry matter of *Phalaris minor* was found in intercropping of wheat with fennel cropping system (3.30 q/ha) which was 43.68 % less as compared to wheat weedy. Intercropping of wheat with dil seed was found at par with intercropping of fennel and both these systems produced significantly less dry matter of *P.minor* than all other weedy cropping systems. The intercropping of wheat with gobhi sarson weedy was found at par with intercropping of wheat with fenugreek weedy cropping system with respect to production of dry matter of *P.minor*.

In the pooled data (2020-21 and 2021-22), maximum dry matter of *Phalaris minor* was found in wheat weedy cropping system (5.77 q/ha) (Table 4.1.2-b). The intercropping of wheat with lentil weedy recorded significantly higher dry matter of *Phalaris minor* than all other cropping system and at par with intercropping of wheat with African sarson weedy cropping system. Among the weedy intercropping systems, the least dry matter of *Phalaris minor* was found in intercropping of wheat with fennel (3.45 q/ha). It was found that dry matter of *Phalaris minor* was 40.2% less in intercropping of wheat with fennel weedy as compared to wheat weedy cropping system which was found at par with intercropping of wheat with dill seed weedy intercropping system. Similar reports were given by Wasaya *et al*., (2013).

Among Brassica crops, Gobhi sarson showed more smothering effect on *Phalaris minor* than African sarson for reducing dry matter of *Phalaris minor* which may be due to broader leaves of gobhi sarson than African sarson. From spices, fenel and dil seed smothered *Phalaris minor* effectively than fenugreek. Also lentil showed poor smothering potential on *Phalaris minor* due to its early slow growth. Reduction in the dry matter of *Phalaris minor* in medicinal cropping system (fennel, dil seed and fenugreek) might be due to release of volatile compounds by these crops which reduced the dry matter of *Phalaris minor*. This may also be due to initial quick growth and wider leaves of fennel and dil seed.

Table 4.1.2.-b: Periodic dry matter of *Phalaris minor* (q/ha) in different intercrops grown in bed planted wheat

Treatments	Dry matter of *Phalaris minor* (q/ha)					
	90DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat, weedy	6.08 (35.9)	6.15 (36.8)	6.11 (36.4)	5.67 (31.2)	5.86 (33.2)	5.77 (32.2)
Wheat+Gobhi sarson, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Gobhi sarson, weedy	4.46 (18.9)	4.34 (17.9)	4.40 (18.4)	4.07 (15.6)	3.55 (11.6)	3.81 (13.6)
Wheat+African sarson, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+African sarson, weedy	4.97 (23.7)	4.63 (20.4)	4.80 (22.0)	4.69 (20.9)	3.83 (13.7)	4.26 (17.4)
Wheat+Lentil, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Lentil, weedy	5.10 (25)	4.89 (22.9)	5.00 (24.0)	4.80 (22.1)	4.69 (21.0)	4.75 (21.6)
Wheat+Fenugreek, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fenugreek, weedy	4.57 (19.9)	4.36 (18.0)	4.47 (18.9)	4.18 (16.5)	3.62 (12.1)	3.90 (14.3)
Wheat+Fennel, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Fennel, weedy	4.22 (16.8)	4.09 (15.7)	4.15 (16.3)	3.60 (11.9)	3.30 (9.9)	3.45 (10.9)
Wheat+Dilseed, weed free	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Wheat+Dilseed, weedy	4.42 (18.5)	4.17 (16.4)	4.30 (17.5)	3.68 (12.6)	3.38 (10.4)	3.53 (11.5)
CD at 5%	0.06	0.08	0.11	0.10	0.13	0.25

Note-Figures in parenthesis are original values, figures without parenthesis are transformed values $\sqrt{x+1}$

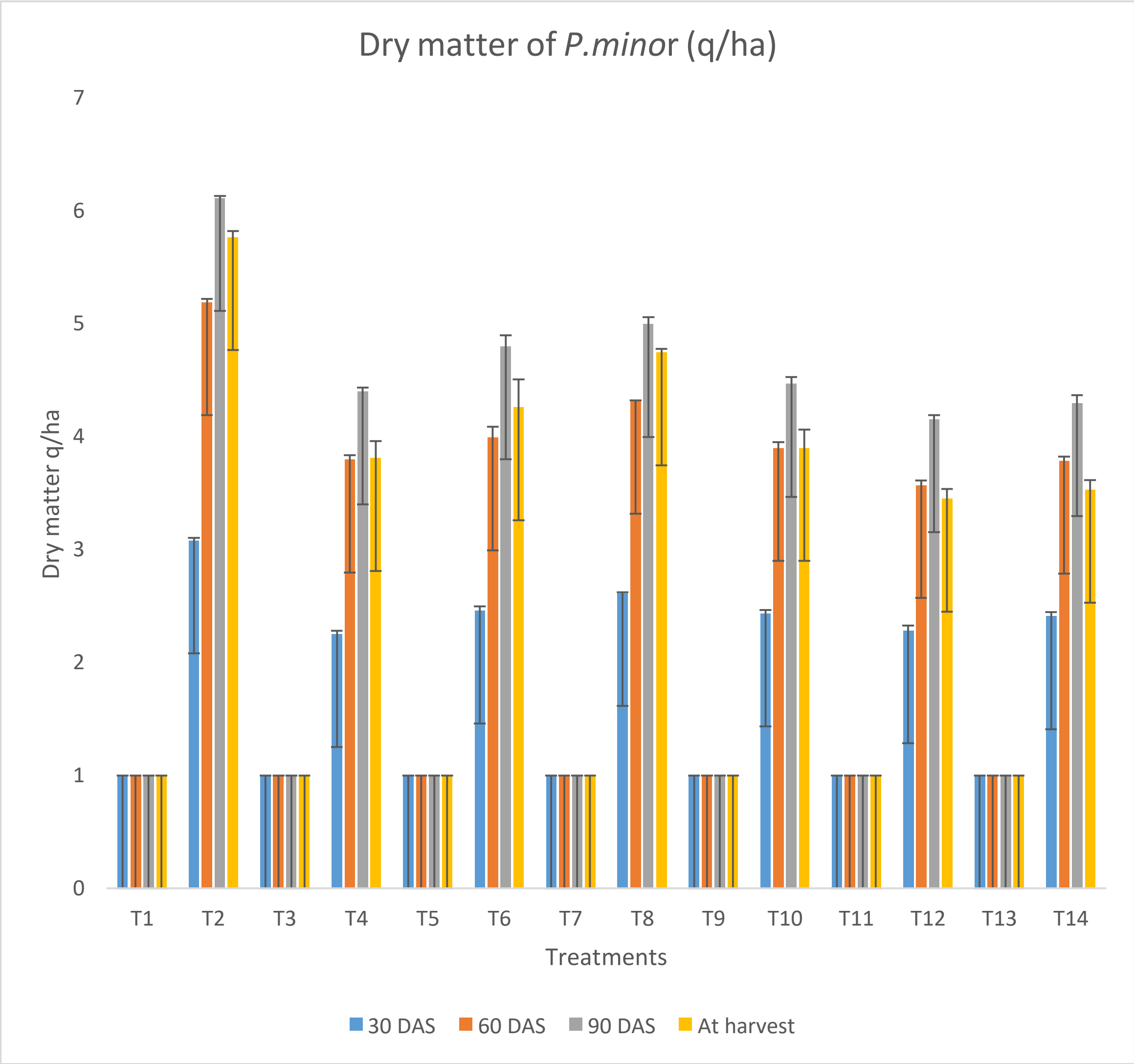


Fig. 4.1.2: Periodic dry matter of *Phalaris minor* (q/ha) in different intercrops grown in bed planted wheat

Note: T1-Wheat weed free, T2-Wheat weedy. T3-Wheat+Gobhi sarson weed free, T4-Wheat+Gobhi sarson weedy, T5-Wheat+African sarson weed free, T6- Wheat+African sarson weedy, T7-Wheat+Lentil weed free, T8-Wheat+Lentil weedy, T9-Wheat+Fenugreek weed free, T10-Wheat+Fenugreek weedy, T11-Wheat+Fennel weed free, T12-Wheat+Fennel weedy, T13-Wheat+Dil seed weed free, T14-Wheat+dil seed weedy

4.2 Growth parameters

4.2.1 Plant height (cm)

Plant height is one of the major growth parameter for the determination of competing ability and growth of the crops as well as the indication of growth promoting or suppressing ability of the treatment. Plant height of wheat recorded at 30, 60, 90 DAS and at harvest was presented in Table 4.2.1.-a and 4.2.1.-b and graphically shown in Fig. 4.1.3. In the first year 2020-21 at 30 DAS the maximum height of wheat was found in the wheat weed free treatment (23.1 cm) followed by intercropping of wheat with fennel weed free treatment (22.0 cm) which were statistically at par (Table 4.2.1-a). The value of height in wheat weed free treatment was statistically at par with intercropping of wheat with African sarson, lentil, fenugreek, fennel and dil seed weed free treatments and were significantly more than intercropping of wheat with gobhi sarson weed free and all other weedy treatments. The height of wheat was 4.2% less in intercropping of wheat with fennel weed free treatment as compare with wheat weed free treatment. From the weed free treatments, the significantly less height was found in intercropping of wheat with gobhi sarson (20.6 cm) than wheat weed free. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson (16.5 cm) which was significantly lower than all weed free treatments. The height of wheat was less by 9.94% by gobhi sarson weedy as compare with wheat weedy treatment.

In the second year (2021-22) at 30DAS, the maximum wheat plant height was found in the wheat weed free treatment (25.6 cm) which was significantly higher than weed free treatments of all tried intercrops (Table 4.2.1-a). The value of height in weed free treatments were significantly higher than all weedy treatments for their respective crops. The height in intercropping of wheat with fennel was found at par with all intercrops weed free treatments. The lowest height among weed free treatments was found in intercropping of wheat with gobhi sarson (20.7 cm) which was at par with wheat intercropped with other intercrops. The height of wheat was 13.35% less in intercropping of wheat with fennel weed free treatment as compare with wheat weed free treatment. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson (16.2 cm) which was significantly less than intercropping of fennel and at par with all other weedy intercropping systems. The height of wheat was decreased by 6.53% in gobhi sarson weedy treatment as compare with wheat weedy treatment.

From the pooled data (2020-21 and 2021-22) recorded at 30 DAS, the maximum height of wheat was found in the wheat weed free treatment (24.3 cm) which was significantly more than in different intercrops (Table 4.2.1-a). The height in intercropping of wheat with fennel was found at par with intercropping of wheat with dil seed, fenugreek and lentil under weedy conditions and was significantly higher from intercropping of wheat with gobhi sarson and African sarson. The significantly less height from weed free treatments was found in intercropping of wheat with gobhi sarson (20.7 cm) than all other intercropping treatments except fenugreek. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson (16.3 cm) which was significantly lower than all other treatments. The height of wheat was decreased by 8.31% in gobhi sarson weedy crop as compare with wheat weedy treatment. All the intercrops in wheat under weedy conditions resulted in significant reduction in wheat plant height recorded 30 DAS as compared to weed free conditions under all respective crops.

In the first year (2020-21) at 60DAS, the maximum height was found in the wheat weed free treatment (61.7 cm) which was significantly more than wheat growing in all intercrops under weed free conditions except fennel and it was significantly high from intercropping of wheat with gobhi sarson, African sarson, lentil and fenugreek and other weedy treatment (Table 4.2.1-a). The lowest height of wheat from weed free treatments was found in intercropping of wheat with gobhi sarson (56.4 cm) which was significantly less than all intercrops in weed free conditions. The height of wheat was 3.8% less in intercropping of wheat with fennel weed free treatment as compare with wheat weed free treatment. The lowest height from all treatments under weedy conditions was found in intercropping of wheat with gobhi sarson (46.3 cm) which was significantly less than wheat in different intercropping systems.

In the second year (2020-21) at 60 DAS, the maximum height of wheat was found in the wheat weed free treatment (66.1 cm) which was significantly more than wheat growing in all intercrops except fennel and dil seed growing in wheat (Table 4.2.1-a) which was found at par with intercropping of wheat with fennel and dil seed. The significantly lowest height from weed free treatments was found in intercropping of wheat with gobhi sarson (56.9 cm) than wheat grown in association with fennel and dil seed. The height of wheat was 3.1% less in intercropping of wheat with fennel weed free treatment as compare with wheat weed free treatment. The lowest height from all treatments was found in intercropping of wheat with gobhi sarson (44.3 cm) under weedy conditions which was significantly lower than all intercropping treatments of wheat except fennel and dil seed. The height of wheat was decreased by 3.2% in gobhi sarson under weedy conditions as compare with wheat weedy treatment.

From the pool data (2020-21 and 2021-22), it may be concluded that maximum height was found in the wheat weed free treatment (63.9 cm) which was significantly more from all other intercropping treatments (Table 4.2.1-a). The intercropping of wheat with fennel was found at par with intercropping of wheat with dil seed under weed free treatment and significantly higher from all other treatments. The significantly less height from weed free treatments was found in intercropping of wheat with gobhi sarson (56.7 cm) than fenugreek, fennel and dil seed. The height of wheat was 3.42% less in intercropping of wheat with fennel than weed free treatment. The lowest height under weedy conditions from all treatments was found in intercropping of wheat with gobhi sarson (45.3 cm) which was significantly lower in wheat growing in all intercrops except fennel and dil seed. The height of wheat decreased by 1.64% in gobhi sarson weedy as compare with wheat weedy treatment.

The plant height of wheat in weedy conditions under all intercrops was found to be significantly less with their respective treatments under weed free conditions when observations were recorded 30 and 60 DAS during 2020-21 and 2021-22 and of pooled analysis. Weed free conditions significantly increased plant height of wheat under different intercrops as compare to weedy conditions of respective crops. Intercropping of gobhi sarson decreased wheat plant height as it over powerded wheat crop whereas fennel and dil seed increased wheat plant height under weedy and weed free conditions.

During the first year (2020-21) when observations were recorded 90DAS, the maximum height was found in the wheat weed free treatment (95.9 cm) which was significantly higher than all other treatments (Table 4.2.1-b). The intercropping of wheat with fennel under weed free was found at par with intercropping of wheat with dil seed and fenugreek and these intercrops resulted in significantly higher wheat plant height than all other treatments. The lowest height of wheat from weed free treatments was found in intercropping of wheat with gobhi sarson (81.7 cm) which was at par with intercropping of African sarson and it was significantly less when all other intercrops were sown in wheat under *P.minor* competition condition. The height of wheat was significantly less with gobhi sarson as intercrop than intercropping of fenugreek where as other

Table 4.2.1-a: Periodic plant height of wheat (cm) as influenced by different intercrops in bed planted technique

Treatments	Plant height of wheat (cm)					
	30 DAS			60DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	23.1	25.6	24.3	61.7	66.1	63.9
Wheat, weedy	18.3	17.3	17.8	46.4	45.8	46.1
Wheat+Gobhi sarson, weed free	20.6	20.7	20.7	56.4	56.9	56.7
Wheat+Gobhi sarson, weedy	16.5	16.2	16.3	46.3	44.3	45.3
Wheat+African sarson, weed free	21.2	21.4	21.3	57.5	57.7	57.6
Wheat+African sarson, weedy	17.6	17.4	17.5	46.4	46.0	46.2
Wheat+Lentil, weed free	21.9	22.1	22.0	57.4	57.9	57.6
Wheat+Lentil, weedy	17.9	17.9	17.9	46.8	46.6	46.7
Wheat+Fenugreek, weed free	21.1	21.3	20.7	57.8	59.7	58.8
Wheat+Fenugreek, weedy	17.6	18.0	17.8	46.8	46.8	46.8
Wheat+Fennel, weed free	22.0	22.2	22.1	59.4	64.1	61.7
Wheat+Fennel, weedy	18.7	18.9	18.8	47.8	48.9	48.3
Wheat+Dilseed, weed free	21.9	22.1	22.0	58.1	63.4	60.7
Wheat+Dilseed, weedy	18.3	18.4	18.3	47.2	47.9	47.5
CD at 5%	2.37	2.21	1.67	3.08	3.11	2.83

intercrops were found at par with gobhi sarson for production of wheat height under weedy conditions.

In the second year (2021-22) at 90 DAS, the maximum height was found in the wheat weed free treatment (97.2 cm) which was found at par with intercropping of wheat with fennel and it was significantly more than intercropping of wheat with gobhi sarson, African sarson, lentil and fenugreek and other weedy treatments for all intercrops (Table 4.2.1-b). The lowest height from weed free treatments was found in intercropping of wheat with gobhi sarson (82.4 cm) which was at par with African sarson intercropping treatment and significantly higher than all other intercrops. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson (72.05 cm) which was significantly lower than all weed free treatments and intercropping of wheat with fennel and dil seed, fenugreek and lentil weedy treatments. Plant height of wheat weedy treatment was found at par with intercropping of wheat with African sarson weedy treatments.

On the basis of pooled data (2020-21 and 2021-22) at 90 DAS, the maximum height was found in the wheat weed free treatment (96.5 cm) which was significantly high than all other treatments (Table 4.2.1-b). The intercropping of wheat with fennel was found at par with intercropping of wheat with dil seed weed free treatment and significantly higher from all other weedy and weed free treatments. The significantly lowest height from weed free treatments was found in intercropping of wheat with gobhi sarson (82.0 cm) than all other treatments. The height of wheat was 4.3% less in intercropping of wheat with fennel weed free treatment as compare with wheat weed free treatment. The lowest height from all treatments was found in intercropping of wheat with gobhi sarson (71.9 cm) which was significantly lower than all weed free treatments and intercropping of wheat with African sarson, fennel, lentil, fenugreek and dil seed weedy treatments and it was found at par with wheat weedy treatment and intercropping of wheat with African sarson weedy treatments.

Highest plant height recorded at harvest during first year (2020-21) was observed in the wheat weed free treatment (104.3 cm) followed by intercropping of wheat with fennel weed free treatment (102.9 cm) (Table 4.2.1-b) which was significantly higher than all other treatments and found at par with intercropping of wheat with fennel weed free treatment. The intercropping of wheat with fennel was found at par with intercropping of wheat with dil seed and fenugreek weed free treatments and these treatments gave significantly higher plant height than all other intercropping systems. The lowest height from weed free treatments was found in intercropping of wheat with gobhi sarson (95.3 cm) which was significantly less when intercropping of fennel, dil seed and fenugreek. The height of wheat was 1.34% less in intercropping of wheat with fennel weed free treatment as compare with wheat weed free treatment. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson (81.1 cm) which was significantly less than all intercrops except African sarson. Plant height was significantly more for wheat in different intercrops when grown under weed free environment as compare to their respective weedy conditions.

In the second year (2021-22) at harvest, the maximum height was found in the wheat weed free treatment (107 cm) followed by intercropping of wheat with fennel weed free treatment (106.1 cm) (Table 4.2.1-b). It was found at par with intercropping of wheat with fennel and dil seed which was significantly more than intercropping of wheat with gobhi sarson, African sarson, lentil and fenugreek under weed free conditions as well as under all weedy treatments. The significantly low height from weed free treatments was found in intercropping of wheat with gobhi sarson (97.0 cm) as compared to intercropping of African sarson and lentil. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson (82.9 cm) which was significantly lower than intercropping of wheat with fennel and dil seed weedy treatments. It was found at par with wheat weedy treatment and intercropping of wheat with African sarson, lentil and fenugreek weedy treatments.

From the pool data at harvest, it can be concluded that the maximum wheat height was found in the wheat weed free treatment (105.7 cm) followed by intercropping of wheat with fennel weed free treatment (104.5 cm) which was significantly more when all other intercrops sown in wheat (under weed free conditions) (Table 4.2.1-b). The intercropping of wheat with fennel weed free treatment recorded significantly higher plant height than all other treatments. The lowest height from weed free treatments was found in intercropping of wheat with gobhi sarson (96.1 cm) which was significantly less when all other intercrops. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson (82.0 cm) which was significantly lower than intercropping of wheat with fennel, lentil, fenugreek and dil seed weedy treatments and was at par with intercropping of wheat with African sarson weedy treatments. The height of wheat was decreased by 2.17% in gobhi sarson when sown as intercrop as compare with wheat weedy treatment. The results were in conformity with Khorramdel *et al*., (2010).

From wheat height data recorded at all periodic intervals during both years, it can be concluded that both fennel and dil seed showed less competition with main crop (wheat) whereas gobhi sarson and African sarson due to their more height than wheat resulted in reduction of wheat plant height. The maximum plant height of wheat was found when it was grown as sole crop. The minimum wheat plant height was found in intercropping of wheat with gobhi sarson weedy cropping system. The reduction in the plant height might be due to aggressive nature of gobhi sarson. Infestations of *Phalaris minor* (weedy treatment) significantly decreased wheat plant height of each intercrop may be due to competition with *Phalaris minor* for all applied inputs.

Table 4.2.1-b: Periodic plant height of wheat (cm) as influenced by different intercrops in bed planting technique

Treatments	Plant height of wheat (cm)					
	90 DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	95.9	97.2	96.5	104.3	107.0	105.7
Wheat, weedy	72.7	73.0	72.8	84.0	83.6	83.8
Wheat+Gobhi sarson, weed free	81.7	82.4	82.0	95.3	97.0	96.1
Wheat+Gobhi sarson, weedy	71.7	72.1	71.9	81.1	82.9	82.0
Wheat+African sarson, weed free	83.2	83.7	83.4	96.4	98.6	97.5
Wheat+African sarson, weedy	72.3	74.3	73.3	82.2	83.2	82.7
Wheat+Lentil, weed free	86.0	87.1	86.6	97.6	99.3	98.4
Wheat+Lentil, weedy	73.9	75.0	74.4	84.1	84.2	84.1
Wheat+Fenugreek, weed free	89.9	90.7	90.3	99.6	101.8	100.7
Wheat+Fenugreek, weedy	73.9	76.8	75.4	84.2	84.2	84.2
Wheat+Fennel, weed free	90.5	94.3	92.4	102.9	106.1	104.5
Wheat+Fennel, weedy	75.1	78.0	76.5	85.7	86.3	86.0
Wheat+Dil seed, weed free	89.7	92.6	91.1	100.1	105.3	102.7
Wheat+Dil seed, weedy	74.3	77.7	76.0	85.6	85.9	85.8
CD at 5%	2.84	2.95	2.40	2.89	2.61	2.30

Fig. 4.1.3: Periodic plant height of wheat (cm) as influenced by different intercrops in bed planting technique

Note: T1-Wheat weed free, T2-Wheat weedy. T3-Wheat+Gobhi sarson weed free, T4-Wheat+Gobhi sarson weedy, T5-Wheat+African sarson weed free, T6- Wheat+African sarson weedy, T7-Wheat+Lentil weed free, T8-Wheat+Lentil weedy, T9-Wheat+Fenugreek weed free, T10-Wheat+Fenugreek weedy, T11-Wheat+Fennel weed free, T12-Wheat+Fennel weedy, T13-Wheat+Dil seed weed free, T14-Wheat+dil seed weedy

4.2.2 Plant height of intercrops (cm)

Plant height was variable for different crops depending upon their genetic potential. During first year (2020-21) at 30DAS, the maximum plant height was found in gobhi sarson weed free (30.5 cm) followed by African sarson weed free (26.7 cm) (Table 4.2.2-a). All weed free treatment of different respective intercrops significantly increased plant height than weedy treatment except fenugreek and dil seed. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy and infestation of *Phalaris minor* decreased 17.32% plant height in gobhi sarson weedy treatment as compared with gobhi sarson weed free treatment. Similarly *P.minor* infestations had decreased 29.92%, 29.82%, 16.49%, 29.59% and 9.27% plant height of intercrops viz. African sarson, lentil, fenugreek, fennel and dil seed respectively compared to their respective weed free treatments. From the medicinal crops, the plant height in fennel crop and dil seed was found at par under weedy and weed free conditions.

During the second year (2021-22) at 30DAS, the maximum plant height was found in intercropping of gobhi sarson in wheat under weed free (35.9 cm) followed by African sarson weed free (33.5 cm) (Table 4.2.2-a). All weed free treatment had significantly higher plant height than weedy treatments for respective crops except fenugreek. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and infestation of *Phalaris minor* decreased 22.42% plant height in gobhi sarson as compared with gobhi sarson weed free treatment. Similarly *Phalaris minor* infestations decreased plant height by 35.22%, 29.46%, 16.66%, 28.22% and 37.44% in African sarson, lentil, fenugreek, fennel and dil seed than weed free treatments respectively. From the medicinal crops, the maximum plant height was observed in fennel crop and it was found at par with dil seed crop.

On the basis of pooled data (2020-21 and 2021-22) at 30 DAS, the maximum plant height was found in intercropping of gobhi sarson weed free (33.2 cm) followed by intercropping of African sarson weed free (30.1 cm) which was significantly more than all other intercrops. All weed free treatment had significantly increased plant height than weedy treatments for all intercrops except fenugreek (Table 4.2.2-a). The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and resulted in 20.06% decreased in plant height due to *P.minor* infestations. Similarly *Phalaris minor* decreased 32.87%, 29.57%, 16.64%, 28.88% and 26.14% plant height of African sarson, lentil, fenugreek, fennel and dil seed respectively while growing in wheat. From the medicinal crops, the maximum plant height was observed in fennel and dil seed crop which was significantly more than fenugreek.

During the first year (2020-21), the maximum plant height recorded 60DAS was found in intercropping of gobhi sarson weed free (83.0 cm) followed by intercropping of African sarson in wheat weed free (72.7 cm) (Table 4.2.2-a). All weed free treatment recorded significantly higher plant height of all intercrops than weedy treatment except lentil and fenugreek. The height of gobhi sarson in weed free was significantly higher than gobhi sarson weedy treatment and infestation of *Phalaris minor* decreased 22.43% plant height in gobhi sarson as compared with weed free treatment. Similarly, a reduction of 17.57%, 10.07%, 13.14%, 42.84% and 27.88% in plant height of African sarson, lentil, fenugreek, fennel and dil seed treatments respectively was observed in weed free over weedy treatments. From the medicinal crops, the maximum plant height was observed in fennel crop and it was at par with dil seed both under weedy and weed free conditions respectively

During second year (2021-22) at 60DAS, the maximum plant height (cm) was found in intercrop of gobhi sarson weed free (84.5 cm) followed by intercrop of African sarson weed free (74.7 cm) (Table 4.2.2-a) which was significantly more than all other intercrops. All weed free treatment recorded significantly more plant height than weedy treatment for all intercrops except fenugreek. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and infestation of *Phalaris minor* decreased 22.92% plant height in gobhi sarson. Similarly, *Phalaris minor* infestation had decreased 35.22%, 14.84 %, 17.52%, 47.96% and 35.64% plant height in intercrops viz African sarson, lentil, fenugreek, fennel and dil seed respectively compared to weed free. From the medicinal crops, significantly more plant height was observed in fennel crop as compared to other crops under weed free conditions.

As evidence from pooled data (2020-21 and 2020-22), the maximum plant height recorded at 60 DAS was found in intercrop gobhi sarson weed free (83.8 cm) followed by African sarson weed free (73.7 cm) and these weed free treatment had significantly higher plant height than weedy treatments (Table 4.2.2-a). The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and *Phalaris minor* decreased 22.68 % plant height of this crop. Similarly, plant height decreased by 17.67 %, 12.55%, 15.46%, 45.52% and 31.87% of African sarson, lentil, fenugreek, fennel and dil seed respectively over their respective weed free treatments. From the medicinal crops, the maximum plant height was observed in fennel crop and it was significantly higher under weedy and weed free conditions respectively than fenugreek and dil seed.

During first year (2020-21) plant height recorded at 90 DAS indicated that maximum height was found in gobhi sarson weed free (124.2 cm) followed by African sarson weed free (94.9 cm) (Table 4.2.2-b). All weed free treatment of different intercrops significantly increased plant height than their respective weedy intercrops. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and infestation of *Phalaris minor* decreased plant height of gobhi sarson by 25.39% over weedy treatment. Similarly infestations of *P.minor* decreased plant height by 18.22%, 24.35%, 23.67%, 35.97% and 21.13% of African sarson, lentil, fenugreek, fennel and dil seed respectively over weed free situations.

In the second year (2021-22) at 90DAS, the maximum plant height was found in gobhi sarson weed free (127.53cm) followed by African sarson weed free (96.5cm) (Table 4.2.2-b). All weed free intercrop significantly increased plant height than their respective weedy treatment. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and *Phalaris minor* infestations decreased 26.95% plant height in gobhi sarson as compared with gobhi sarson weed free treatment. Similarly *P.minor* infestation decreased plant height by 19.03%, 25%, 24.24%, 26.81% and 24.31% of African sarson, lentil, fenugreek, fennel and dil seed compared to weed free treatments respectively.

As indicated by the pooled data (2020-21 and 2021-22) at 90 DAS, the significantly more plant height was found in intercropping of gobhi sarson under weed free conditions (125.9 cm) followed by intercropping of African sarson weed free (95.7 cm) (Table 4.2.2-b) as compare to other intercrops. All weed free treatment significantly increased plant height of respective crops compared to weedy treatments. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and *Phalaris minor* infestation significantly decreased plant height by 26.18% in gobhi sarson as compared with gobhi sarson weed free treatment. Similarly *P.minor* decreased plant height by 18.26%, 24.67%, 23.96%, 26.65% and 22.78% in African sarson, lentil, fenugreek, fennel and dil seed weed free treatments respectively over their respective weed free treatment.

Table 4.2.2- a: Periodic plant height (cm) of intercrops in bed planted wheat

Treatments	Plant height of intercrops (cm)					
	30DAS			60DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat+Gobhi sarson, weed free	30.5	35.9	33.2	83.0	84.5	83.8
Wheat+Gobhi sarson, weedy	25.2	27.9	26.5	64.4	65.1	64.8
Wheat+African sarson, weed free	26.7	33.5	30.1	72.7	74.7	73.7
Wheat+African sarson, weedy	18.7	21.7	20.2	60.0	61.5	60.7
Wheat+Lentil, weed free	8.6	11.1	9.8	21.8	23.6	22.7
Wheat+Lentil, weedy	6.0	7.9	6.9	19.6	20.1	19.9
Wheat+Fenugreek, weed free	7.6	8.3	7.9	19.8	22.7	21.2
Wheat+Fenugreek, weedy	6.3	6.9	6.6	17.2	18.7	17.9
Wheat+Fennel, weed free	9.7	10.6	10.2	37.2	40.8	39.0
Wheat+Fennel, weedy	6.9	7.6	7.2	21.3	21.2	21.2
Wheat+Dil seed, weed free	7.3	11.0	9.1	34.5	36.8	35.6
Wheat+Dil seed, weedy	6.7	6.9	6.8	24.9	23.7	24.3
CD at 5%	2.03	2.13	1.75	3.59	3.56	2.11

During the first year (2020-21) at harvest, the maximum plant height was found in intercropping of wheat with Gobhi sarson weed free (151.1 cm) followed by intercropping of wheat with gobhi sarson weedy (120.7 cm) (Table 4.2.2-b) which was significantly more than all other intercrops. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment. All weed free treatment had significantly increased plant height of different intercrop than their respective weedy treatment. The *Phalaris minor* decreased plant height in gobhi sarson weedy treatment by 20.09% as compared with gobhi sarson weeds free treatment. Similarly *P.minor* infestations decreased plant height by 21.78%, 26.08%, 22.64%, 20.96% and 22.14% of African sarson, lentil, fenugreek, fennel and dil seed respectively over their respective weed free treatments.

During the second year (2021-22) at harvest, the maximum plant height was found in intercropping of wheat with gobhi sarson weed free (153.1 cm) followed by intercropping of wheat with gobhi sarson weedy (122.7 cm) (Table 4.2.2-b). The height of gobhi sarson under weed free was significantly higher than gobhi sarson weedy treatment. All weed free treatments had significantly more plant height of different intercrops than weedy treatment. The infestation of *Phalaris minor* decreased plant height in gobhi sarson weedy treatment by 19.83% as compared with gobhi sarson weed free treatment. Similarly *P.minor* infestations decreased plant height by 19.63 %, 30.84%, 23.08%, 22.90% and 25.91% of African sarson, lentil, fenugreek, fennel and dil seed as compared to weed free treatments respectively.

It can be concluded from pooled data that (2020-21 and 2021-22), the maximum plant height was found in gobhi sarson weed free (152.1 cm) followed by intercropping of wheat with gobhi sarson weedy (121.7 cm) (Table 4.2.2-b) which was significantly more than the height of all other intercrops. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment. All weed free treatment for different intercrops significantly increased plant height than weedy treatment for their respective intercrops. The *Phalaris minor* decreased 19.96 % plant height in gobhi sarson weedy treatment as compared with gobhi sarson weeds free treatment. Similarly *Phalaris minor* infestation had decreased plant height by 18.78%, 28.51%, 22.87%, 21.96% and 24.08% in African sarson, lentil, fenugreek, fennel and dil seed treatments respectively as compared to their respective weed free treatments.

The statistical analysis of plant height of different intercrops was done only to meet the statistical requirements of generated data. The maximum height was found gobhi sarson weed free treatment which might be due to high genetic potential of gobhi sarson than other crops. The height of African sarson was less than gobhi sarson but more than all other intercrops. Lentil and fenugreek have genetically less plant height than all tried intercrops and these crops were followed by fennel and dil seed with respect to plant height.

Table 4.2.2-b: Periodic plant height (cm) of different intercrops in bed planted wheat

Treatments	Plant height of intercrops (cm)					
	90DAS			At Harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat+Gobhi sarson, weed free	124.2	127.5	125.9	151.1	153.1	152.1
Wheat+Gobhi sarson, weedy	92.7	93.2	92.9	120.7	122.7	121.7
Wheat+African sarson, weed free	94.9	96.5	95.7	113.2	119.7	116.5
Wheat+African sarson, weedy	77.6	78.1	77.9	93.0	96.2	94.6
Wheat+Lentil, weed free	39.0	41.0	40.0	47.2	49.0	48.1
Wheat+Lentil, weedy	29.5	30.8	30.1	34.9	33.9	34.4
Wheat+Fenugreek, weed free	49.3	53.3	51.3	70.0	72.0	71.0
Wheat+Fenugreek, weedy	37.7	40.4	39.0	54.1	55.4	54.8
Wheat+Fennel, weed free	57.9	63.7	60.8	88.9	93.6	91.3
Wheat+Fennel, weedy	42.6	46.6	44.6	70.3	72.2	71.2
Wheat+Dil seed, weed free	60.0	64.5	62.2	86.5	92.2	89.4
Wheat+Dil seed, weedy	47.3	48.8	48.0	67.3	68.3	67.8
CD at 5%	3.73	3.62	3.41	4.04	4.00	2 .81

4.2.3 Dry matter of wheat (q/ha)

Dry matter of wheat was noted periodically at 30, 60, 90 DAS and at harvest as shown in Table 4.2.3-a and 4.2.3-b and graphically shown in Fig.4.1.4. During the first year (2020-21) at 30 DAS, it had been found that significantly maximum DM)(dry matter) of wheat (q/ha) was found in wheat weed free intercropping system (7.88 q/ha) (Table 4.2.3-a). Among the weed free intercropping systems, the intercropping of wheat with fennel gave higher dry matter. The wheat along with gobhi sarson gave minimum wheat dry matter and was found at par with African sarson and fenugreek. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson intercropping system (2.10 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with intercropping of wheat with African sarson, lentil, fenugreek and dil seed. It was also at par with wheat weedy.

In the second year (2020-21) at 30 DAS, it had been found that significantly maximum DM(dry matter) of wheat was found in wheat weed free intercropping system (8.03 q/ha) (Table 4.2.3-a). Among the weed free intercropping systems, the intercropping of wheat with fennel gave significantly higher dry matter. The intercropping of wheat with gobhi sarson gave minimum wheat dry matter and was found at par with African sarson and fenugreek. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson cropping system (1.92 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with intercropping of wheat with African sarson, lentil, fenugreek and wheat weedy.

From the pool data (2020-21 and 2021-22) analysis, significantly maximum dry matter of wheat was found in wheat weed free intercropping system (7.95 q/ha) (Table 4.2.3-a). Among the weed free intercropping systems, the intercropping of wheat with fennel gave significantly higher dry matter than. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson cropping system (2.01 q/ha) which was significantly less than all weedy intercropping systems but was found at par with intercropping of wheat with African sarson and wheat weedy.

During the first year (2020-21) at 60 DAS, it had been found that significantly maximum dry matter of wheat was found in wheat weed free intercropping system (25.25 q/ha) except fennel and dill seed weed free (Table 4.2.3-a). Among the weed free intercropping systems, the intercropping of wheat with fennel gave higher dry matter. The wheat along with gobhi sarson gave minimum wheat dry matter and was found at par with African sarson, lentil and fenugreek. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson cropping system (14.78 q/ha) which was significantly lower than fennel and dil seed intercropping systems but was found at par with intercropping of wheat with African sarson, lentil, fenugreek and wheat weedy.

In the second year (2020-21) at 60 DAS, it had been found that maximum dry matter of wheat was found in wheat weed free intercropping system (26.25 q/ha) which was significantly higher than all other intercropping systems except fennel and dill seed weed free (Table 4.2.3-a). Among the weed free intercropping systems, the intercropping of wheat with fennel and dil seed gave significantly higher dry matter. The wheat along with gobhi sarson cropping system gave minimum wheat dry matter and was found at par with African sarson, lentil and fenugreek. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson cropping system (15.10 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with intercropping of wheat with African sarson and lentil. It was also at par with wheat weedy.

From the pool data (2020-21 and 2021-22) at 60 DAS, that maximum dry matter of wheat was found in wheat weed free intercropping system (25.75 q/ha) which was significantly higher than all other intercropping systems except fennel and dill seed weed free (Table 4.2.3-a). Among the weed free intercropping systems, the intercropping of wheat with fennel and dil seed gave significantly higher dry matter than all other intercropping systems. The intercropping of wheat with gobhi sarson gave minimum wheat dry matter which was found at par with African sarson,

Table 4.2.3-a: Periodic dry matter of wheat in different intercrops grown in bed planted wheat

Treatments	Dry matter of wheat (q/ha)					
	30DAS			60DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	7.88	8.03	7.95	25.25	26.25	25.75
Wheat, weedy	2.23	2.12	2.17	15.50	16.17	15.84
Wheat+Gobhi sarson weed free	4.53	4.68	4.60	21.95	22.08	22.02
Wheat+Gobhi sarson weedy	2.10	1.92	2.01	14.78	15.10	14.94
Wheat+African sarson weed free	4.73	5.30	5.01	22.23	22.16	22.19
Wheat+African sarson weedy	2.25	2.12	2.18	15.63	16.25	15.94
Wheat+Lentil weed free	5.45	5.99	5.72	22.58	22.98	22.78
Wheat+Lentil Weedy	2.35	2.46	2.40	16.18	16.63	16.40
Wheat+Fenugreek weed free	5.10	5.51	5.30	22.90	23.03	22.96
Wheat+Fenugreek weedy	2.50	2.63	2.56	16.85	17.41	17.13
Wheat+Fennel weed free	6.25	7.75	7.00	24.55	25.83	25.19
Wheat+Fennel weedy	3.18	3.20	3.19	18.55	18.70	18.63
Wheat+Dilseed weed free	5.80	6.53	6.17	23.83	25.43	24.63
Wheat+Dilseed weedy	2.80	3.08	2.94	17.70	18.34	18.02
CD at 5%	0.87	0.34	0.37	2.13	0.92	0.95

lentil and fenugreek. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson cropping system (14.94 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with intercropping of wheat with wheat weedy. The African sarson was found at par with lentil for producing dry matter of wheat.

During the first year (2020-21) at 90 DAS, it had been found that maximum dry matter of wheat was found in wheat weed free intercropping system (43.73 q/ha) which was significantly higher than all other intercropping systems except fennel (Table 4.2.3-b). Among the weed free intercropping systems, the intercropping of wheat with fennel gave significantly higher dry matter than gobhi sarson, African sarason and lentil intercropping systems. The intercropping of wheat with gobhi sarson gave minimum wheat dry matter. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson cropping system (26.45 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with intercropping of wheat with African sarson, and wheat weedy. The dry matter of wheat in lentil was found at par with fenugreek and dil seed.

In the second year (2021-22) at 90 DAS, it was found that maximum dry matter of wheat was found in wheat weed free intercropping system (45.89 q/ha) which was significantly higher than all other intercropping systems except fennel (Table 4.2.3-b). Among the weed free intercropping systems, the intercropping of wheat with fennel and dil seed gave at par dry matter of wheat with wheat alone. The intercropping of wheat with gobhi sarson gave significantly less wheat dry matter than all intercropping systems except African sarson. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson intercropping (27.68 q/ha) which was significantly less than all weedy intercropping systems but was found at par with intercropping of wheat with African sarson, and wheat weedy. The dry matter of wheat in lentil was found at par with fenugreek and dil seed.

From the pool data (2020-21 and 2021-22) at 90 DAS, the maximum dry matter of wheat was found in wheat weed free intercropping system (44.81 q/ha) which was significantly higher than all other intercropping systems (Table 4.2.3-b). Among the weed free intercropping systems, the intercropping of wheat with fennel and dil seed gave significantly higher dry matter. The intercropping of wheat with gobhi sarson gave significantly less wheat dry matter than others intercropping systems. The African sarson was noted statistically at par with lentil. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson (27.68 q/ha) which was significantly less than all weedy intercropping systems The dry matter of wheat in wheat weedy was found at par with African sarson and lentil.

During the first year (2020-21) at harvest, it was found that maximum dry matter of wheat was found in wheat weed free intercropping system (63.65 q/ha) except fennel and dil seed (Table 4.2.3-b). Among the weed free intercropping systems, the intercropping of wheat with fennel gave higher dry matter than all other intercropping systems. The intercropping of wheat with gobhi sarson gave significantly less wheat dry matter than all other intercropping systems. The intercropping of African sarson was found at par with lentil. For producing dry matter of wheat among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson cropping system (37.75 q/ha) which was significantly less than all weedy intercropping systems but was found at par with wheat weedy. The lentil was found at par with fenugreek with respect to dry matter productivity by wheat.

In the second year (2021-22) at harvest, it was found that maximum dry matter of wheat was found in wheat weed free intercropping system (65.92 q/ha) except fennel (Table 4.2.3-b). Among the weed free intercropping systems, the intercropping of wheat with fennel gave significantly higher dry matter of wheat. The intercropping of wheat with gobhi sarson gave significantly less wheat dry matter of wheat than all other intercropping system. The dry matter of wheat in African sarson was found at par with lentil. Among the weedy intercropping systems, the minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson (38.55 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with wheat weedy. The lentil was found at par with fenugreek for dry matter production by wheat.

From the analysis of pooled data (2020-21 and 2021-22), the maximum dry matter of wheat was found in wheat weed free intercropping system (64.79 q/ha) which was significantly higher than all other intercropping systems except fennel (Table 4.2.3-b). Among the weed free intercropping systems, the intercropping of wheat with fennel gave significantly more dry matter. The wheat along with gobhi sarson gave significantly less wheat dry matter than all other intercropping systems. The dry matter of wheat in African sarsonwas recorded statistically at par with lentil. Among weedy intercropping systems, minimum dry matter of wheat was found in intercropping of wheat with gobhi sarson (38.15 q/ha) which was significantly lower than all weedy intercropping systems but was found at par with wheat weedy. The lentil was found at par with fenugreek with respect to wheat dry matter production.

The dry matter production by wheat at all periodic stages, was not influenced with intercropping of fennel and dil seed indicating that these are highly compatible for intercropping in bed planted wheat without any adverse effect on grain yield of main crops. These crops are highly compatable as intercrop in bed planted wheat. On the other hand, intercropping of gobhi sarson or African sarson had slight adverse effect on growth and development of wheat due to their tall growing habits which suppressed growth of main crop (wheat).

Table 4.2.3-b: Periodic dry matter of wheat (q/ha) in different intercrops grown in bed planted wheat

Treatments	Dry matter of wheat (q/ha)					
	90DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	43.73	45.89	44.81	63.65	65.92	64.79
Wheat, weedy	28.18	28.38	28.28	39.13	39.69	39.41
Wheat+Gobhi, sarson weed free	37.08	39.86	38.47	55.28	58.62	56.95
Wheat+Gobhi, sarson weedy	26.45	27.68	27.06	37.75	38.55	38.15
Wheat+African, sarson weed free	39.78	40.61	40.19	57.33	59.74	58.53
Wheat+African, sarson weedy	28.23	28.63	28.43	39.88	40.63	40.25
Wheat+Lentil, weed free	40.38	41.42	40.90	57.73	61.66	59.69
Wheat+Lentil, weedy	28.35	29.11	28.73	40.00	40.82	40.41
Wheat+Fenugreek, weed free	41.05	42.87	41.96	59.45	62.44	60.94
Wheat+Fenugreek, weedy	29.15	29.67	29.41	40.78	41.62	41.20
Wheat+Fennel, weed free	42.68	44.97	43.82	62.73	65.21	63.97
Wheat+Fennel, weedy	30.28	31.33	30.80	43.30	44.12	43.71
Wheat+Dil seed, weed free	41.53	44.37	42.95	62.08	64.24	63.16
Wheat+Dil seed, weedy	30.13	30.49	30.31	42.65	42.73	42.69
CD at 5%	1.88	1.25	0.76	1.97	1.35	1.01

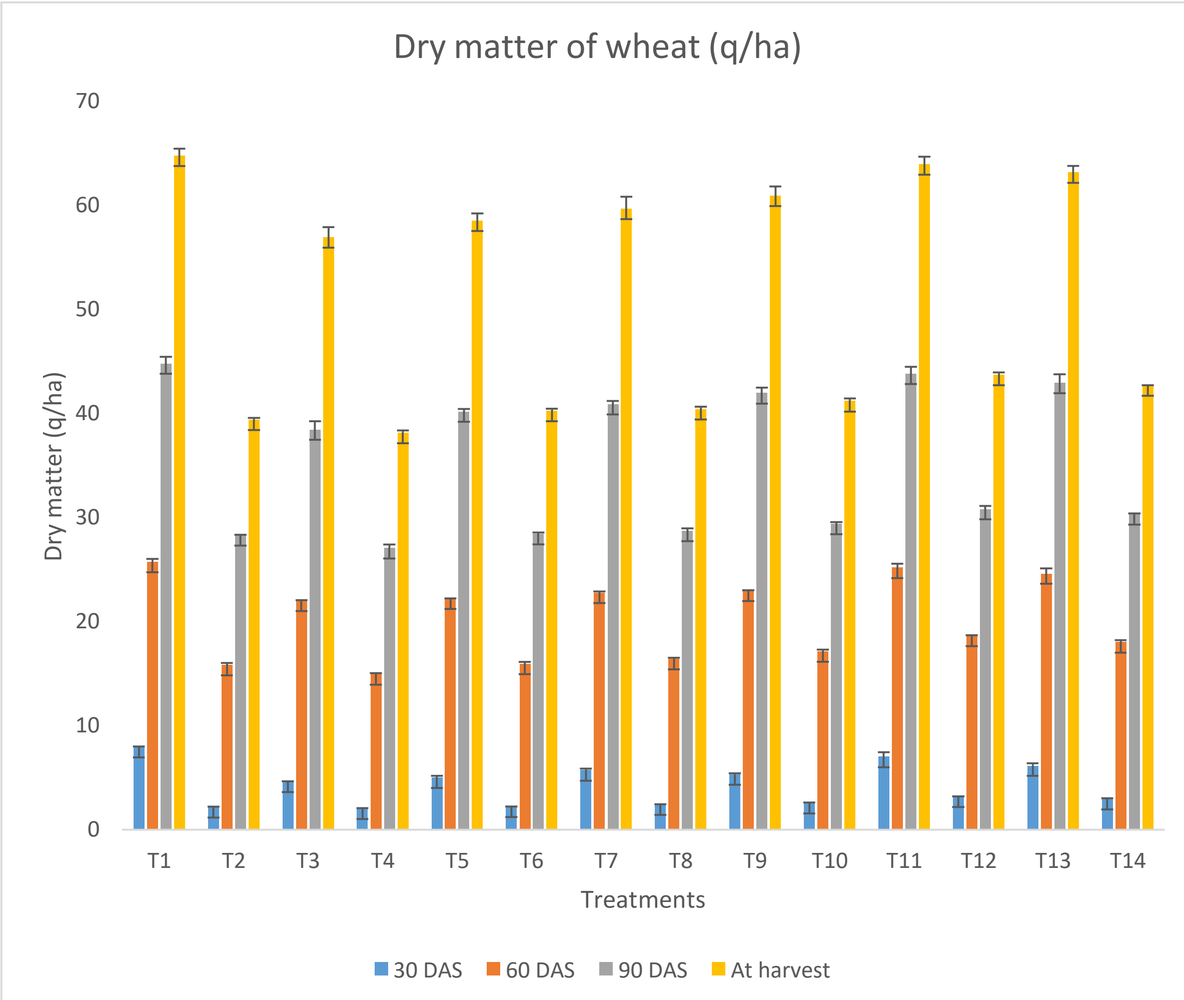


Fig.4.1.4: Periodic dry matter of wheat (q/ha) in different intercrops grown in bed planted wheat

Note: T1-Wheat weed free, T2-Wheat weedy, T3-Wheat+Gobhi sarson weed free, T4-Wheat+Gobhi sarson weedy, T5-Wheat+African sarson weed free, T6-Wheat+African sarson weedy, T7-Wheat+Lentil weed free, T8-Wheat+Lentil weedy, T9-Wheat+Fenugreek weed free, T10-Wheat+Fenugreek weedy, T11-Wheat+Fennel weed free, T12-Wheat+Fennel weedy, T13-Wheat+Dil seed weed free, T14-Wheat+dil seed weedy

4.2.4 Number of tillers (per m row length)

Tillers are the major yield attributes which was responsible for both grain and straw yield. The no. of tillers were noted at 30, 60, 90 DAS and at harvesting time as shown in Table 4.2.4-a and 4.2.4-b and graphically shown in Fig.4.1.5. During the first year (2020-21) at 30 DAS, it was observed that among all the cropping systems significantly maximum numbers of tillers per m row length were found in the wheat weed free (39.5) and this system was statistically at par with intercropping of wheat with fennel and with dil seed weed free cropping system (Table 4.2.4-a). From the weed free cropping systems, the minimum number of tillers was observed in intercropping of wheat with gobhi sarson (30.5) which was found at par with intercropping of wheat with African sarson and lentil. From the weedy cropping system, the minimum count of tillers was found in intercropping of wheat with gobhi sarson (22.5) which was found at par with intercropping of wheat with African sarson, lentil, fenugreek and wheat. All weed free cropping systems of all intercrops resulted in significantly more number of tillers per meter row length than their respective weedy cropping systems.

In the second year (2021-22) at 30 DAS, it was observed that the maximum numbers of tillers were found in the wheat weed free cropping system (42.8) and this system was statistically at par with intercropping of wheat with fennel and dil seed under weed free cropping system (Table 4.2.4- a). From the weed free cropping systems, the minimum numbers of tillers of wheat were observed in intercropping of wheat with gobhi sarson (34.8) which were at par with intercropping of wheat with African sarson, lentil and fenugreek under weed free cropping system. From the weedy cropping system, the minimum count of tillers was found in intercropping of wheat with gobhi sarson (22.8) which were found at par with intercropping of wheat with African sarson, lentil and wheat weedy. All the weed free cropping systems of all crops resulted in significantly more number of tillers per meter row length than their respective weedy cropping systems.

From the pooled data of (2020-21 and 2021-22) at 30 DAS, among all cropping systems significantly maximum number of tillers were found in the wheat weed free cropping system (41.1) (Table 4.2.4-a). The intercropping of wheat with fennel recorded at par wheat tillers with dil seed cropping system. These cropping systems of fennel and dil seed produced significantly higher tillers per meter row length than all weedy cropping systems. From the weed free cropping system, the minimum number of tillers were observed in intercropping of wheat with gobhi sarson (32.6) which were at par with intercropping of wheat with African sarson. From the weedy cropping systems, the minimum count of tillers was found in intercropping of wheat with gobhi sarson (22.6) which was found at par with intercropping of wheat with African sarson and wheat weedy. The infestation of *Phalaris minor* resulted in significant reduction of tillers of wheat on comparison with wheat when they are grown under weed free conditions for their respective crops.

At 60 DAS during 2020-21, it was observed that the maximum numbers of tillers were found in the wheat weed free cropping system (79.8) (Table 4.2.4-a) and these were statistically at par with intercropping of wheat with fennel and dil seed weed free cropping system. These cropping systems were significantly higher than all weedy cropping systems with respect of no. of tillers of wheat per meter row length. From the weed free cropping systems, the minimum numbers of tillers of wheat were observed in intercropping of wheat with gobhi sarson (71.8) which were found at par with intercropping of African sarson and lentil in wheat. From the weedy cropping system, the minimum count of tillers were found in intercropping of wheat with gobhi sarson weedy cropping system (61.3) which was found at par with intercropping of wheat with African sarson, lentil, fenugreek and wheat weedy cropping system.

In the second year (2021-22) at 60 DAS, it was observed that the maximum numbers of tillers of wheat counted at 60DAS were found in the wheat weed free cropping system (82.0) which was found at par with intercropping of wheat with fennel and dil seed cropping system (Table 4.2.4-a). These cropping systems were found significantly higher than all weedy cropping systems. From the weed free cropping system, the minimum number of tillers was observed in intercropping of wheat with gobhi sarson (72.0) which were found at par with intercropping of wheat with African sarson and lentil. From the weedy cropping systems, the minimum count of tillers of wheat were found in intercropping of wheat with gobhi sarson (62) which was found at par with intercropping of wheat with African sarson, lentil, fenugreek and wheat weedy.

From the pooled data of (2020-21 and 2021-22) at 60DAS, the maximum number of tillers was found in the wheat weed free cropping system (80.9) which were significantly higher than all other cropping systems (Table 4.2.4-a). From the weed free cropping systems, the minimum numbers of tillers were observed in intercropping of wheat with gobhi sarson (73.8) which were found at par with intercropping of wheat with African sarson. From the weedy cropping systems, the minimum count of tillers of wheat were found in intercropping of wheat with gobhi sarson (61.6). These systems were found at par with wheat weedy. Tillers of wheat were significantly reduced by intercropping of all crops under weedy conditions as compared to their respective crops under weed free conditions.

During first year (2020-21) at 90 DAS, it was observed that the maximum numbers of tillers were found in the wheat weed free cropping system (101.8) which were statistically at par with intercropping of wheat with fennel (Table 4.2.4-b). These cropping systems recorded significantly higher total wheat tillers than all weedy cropping systems. From the weed free cropping systems, the minimum number of tillers were observed in intercropping of wheat with gobhi sarson (89.5) which was found at par with intercropping of wheat with African sarson and intercropping of wheat with lentil. From the weedy cropping systems, the minimum count of tillers was found in intercropping of wheat with gobhi sarson (71.3) which was recorded at par with wheat weedy. The intercropping of wheat with African sarson weedy cropping system recorded total wheat tillers statistically at par with intercropping of wheat with lentil weedy cropping system.

In the second year (2021-22), it was observed that the maximum numbers of tillers recorded at 90 DAS were found in the wheat weed free cropping system (104.5) (Table 4.2.4-b). which were statistically at par with intercropping of wheat with fennel weed free cropping system. The intercropping of wheat with dil seed was found statistically at par with intercropping of wheat with fenugreek weed free cropping system. These cropping systems were significantly higher than all weedy cropping systems. From the weed free cropping systems, the minimum number of tillers were observed in intercropping of wheat with gobhi sarson (91.5) and it was found at par with intercropping of wheat with African sarson and lentil. From the weedy cropping systems, the minimum count of tillers was found in intercropping of wheat with gobhi sarson (72) which was found at par with intercropping of wheat with African sarson and wheat weedy.

Table 4.2.4-a: Periodic number of total tillers per meter row length in bed planted technique as influenced by different intercrops

Treatments	Number of total tillers per row length					
	30DAS			60DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	39.5	42.8	41.1	79.8	82.0	80.9
Wheat, weedy	23.0	23.5	23.3	61.5	62.8	62.1
Wheat+Gobhi sarson, weed free	30.5	34.8	32.6	71.8	72.0	71.9
Wheat+Gobhi sarson, weedy	22.5	22.8	22.6	61.3	62.0	61.6
Wheat+African sarson, weed free	32.3	32.0	32.13	73.3	74.3	73.8
Wheat+African sarson, weedy	24.3	24.5	24.4	62.0	63.0	62.5
Wheat+Lentil, weed free	32.5	33.5	33.0	73.5	75.0	74.3
Wheat+Lentil, weedy	24.8	25.3	25.0	62.8	64.0	63.4
Wheat+Fenugreek, weed free	33.8	36.3	35.0	74.8	76.8	75.8
Wheat+Fenugreek, weedy	25.3	26.0	25.6	63.8	64.8	64.3
Wheat+Fennel, weed free	37.8	41.0	39.4	78.3	81.3	79.8
Wheat+Fennel, weedy	27.8	28.8	28.3	67.0	69.3	68.1
Wheat+Dil seed, weed free	36.5	40.3	38.4	77.8	80.0	78.9
Wheat+Dil seed, weedy	27.0	28.3	27.6	66.0	67.3	66.6
CD at 5%	3.22	2.91	2.30	2.77	3.39	2.62

From the pooled data of 2020-21 and 2021-22, among all cropping systems significantly maximum numbers of tillers were recorded at 90DAS were found in the wheat weed free cropping system (103.13) (Table 4.2.4-b). From the weed free cropping systems, the minimum numbers of tillers were observed in intercropping of wheat with gobhi sarson (90.5) and it was significantly lower than all weed free cropping system. From the weedy cropping systems, the minimum count of wheat tillers was found in intercropping of wheat with gobhi sarson (71.6) which was significantly lower than all other cropping system.

During the first year (2020-21) tiller count at harvest revealed that the maximum numbers of tillers were found in the wheat weed free cropping system (97.3). These systems were found statistically at par with intercropping of wheat with fennel and dil seed under weed free cropping system (Table 4.2.4-b). These cropping systems were significantly higher than all weedy cropping systems. From the weed free cropping system, the minimum numbers of tillers were observed in intercropping of wheat with gobhi sarson (85.3) which were found at par with intercropping of wheat with African sarson lentil. From the weedy cropping systems, the minimum count of tillers was found in intercropping of wheat with gobhi sarson (66.3) which was found at par with intercropping of wheat with African sarson, lentil and wheat weedy.

In the second year (2021-22), it was observed that the maximum numbers of tillers at the time of harvest were found in the wheat weed free cropping system (98.5) (Table 4.2.4-b). These were statistically at par with intercropping of wheat with fennel and dil seed under weed free cropping system. These cropping systems were found significantly higher than all weedy cropping systems for production of wheat tillers. From the weed free cropping system, the minimum numbers of tillers were observed in intercropping of wheat with gobhi sarson (86.3) which was found at par with intercropping of wheat with African sarson. From the weedy cropping system, the minimum count of tillers was also found in intercropping of wheat with gobhi sarson (67.5) which was found at par with intercropping of wheat with African sarson and wheat weedy.

During the harvesting time frrom the pooled data (2020-21 and 2021-22), among all other cropping systems significantly maximum numbers of tillers were found in the wheat weed free cropping system (97.9) (Table 4.2.4-b). From the weed free cropping systems, the minimum numbers of tillers were observed in intercropping of wheat with gobhi sarson (85.8) which were significantly lower than all weed free cropping system. From the weedy cropping systems, the minimum count of tillers was found in intercropping of wheat with gobhi sarson (66.9) which were significantly lower than all other cropping systems. Infestation of *Phalaris minor* significantly reduced number of tillers of wheat under all intercropping system compared to weed free conditions under their respective crops. This result was inconformity with Wasaya et al., (2013).

Total tillers of wheat recorded at periodic intervals were not influenced with the intercropping of fennel and dil seed due to its most suitability as intercrops in wheat and these are statistically at par with weed free treatment. On the other hand gobhi sarson, African sarson reduced tiller count of wheat due to their shading effect.

Table 4.2.4-b: Periodic number of total tillers of wheat in bed planted technique as influenced by different intercrops

Treatments	Number of total tillers per meter row length					
	90DAS			At harvest		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Wheat, weed free	101.8	104.50	103.13	97.3	98.5	97.9
Wheat, Weedy	72.3	73.0	72.6	68.3	68.8	68.5
Wheat+Gobhi sarson, weed free	89.5	91.5	90.5	85.3	86.3	85.8
Wheat+Gobhi sarson, weedy	71.3	72.0	71.6	66.3	67.5	66.9
Wheat+African sarson, weed free	90.0	93.3	91.6	86.5	87.3	86.9
Wheat+African sarson, weedy	73.8	74.3	74.0	69.5	69.8	69.6
Wheat+Lentil, weed free	91.8	94.5	93.1	88.5	89.8	89.1
Wheat+Lentil, weedy	75.3	76.5	75.9	72.3	72.8	72.5
Wheat+Fenugreek, weed free	96.3	98.0	97.1	92.3	94.8	93.5
Wheat+Fenugreek, weedy	78.5	79.8	79.1	74.3	74.5	74.4
Wheat+Fennel, weed free	99.8	102.5	101.1	95.5	97.3	96.4
Wheat+Fennel, weedy	80.3	81.5	80.9	77.3	78.3	78.0
Wheat+Dil seed, weed free	98.3	100.3	99.3	94.0	96.0	95.0
Wheat+Dil seed, weedy	79.5	80.8	80.1	76.0	76.5	76.3
CD at 5%	2.34	3.15	2.51	4.09	2.88	3.46

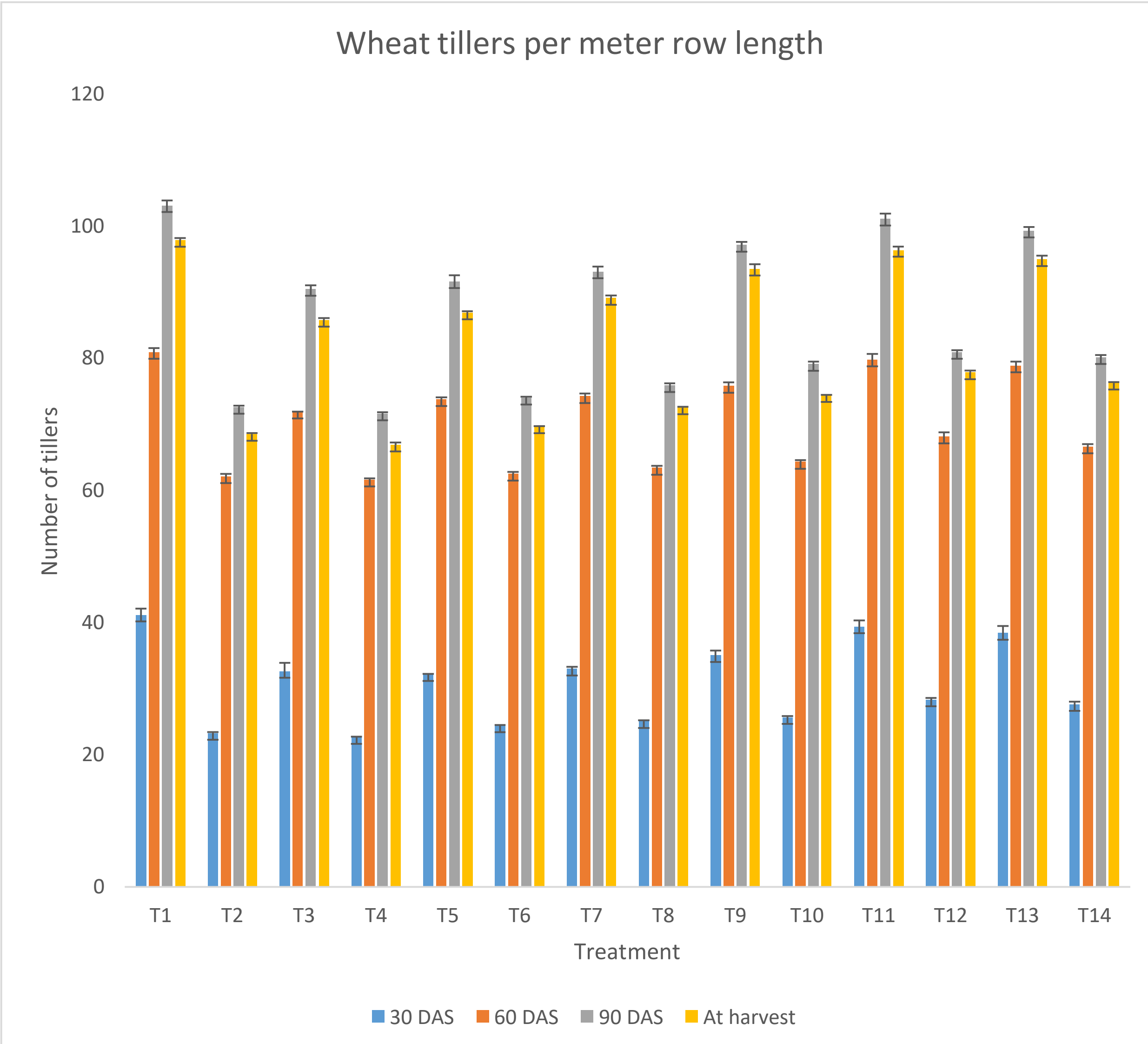


Fig. 4.1.5: Periodic number of total tillers of wheat in bed planted technique as influenced by different intercrops

Note: T1-Wheat weed free, T2-Wheat weedy, T3-Wheat+Gobhi sarson weed free, T4-Wheat+Gobhi sarson weedy, T5-Wheat+African sarson weed free, T6-Wheat+African sarson weedy, T7-Wheat+Lentil weed free, T8-Wheat+Lentil weedy, T9-Wheat+Fenugreek weed free, T10-Wheat+Fenugreek weedy, T11-Wheat+Fennel weed free, T12-Wheat+Fennel weedy, T13-Wheat+Dil seed weed free, T14-Wheat+dil seed weedy

4.2.5 Effective tillers per meter row length

Effective tillers are directly related to wheat yield. More the effective tillers, higher will be the grain yield. The real index of the crop-weed competition is reflected by the growth of either crop or weed. The tillers per unit area or tillers per plant are important parameters which indicate the mutual sharing of space and hence recorded for *P. minor* infestations in wheat to notice its competitive ability. The effective tillers were noted at time of harvest are shown in (Table 4.2.5). During the first year (2020-21) it was observed that the maximum effective tillers were found in the wheat weed free cropping system (84.8). The weed free cropping system was statistically at par with intercropping of wheat with fennel & dil seed and all these cropping systems gave significantly higher effective tillers than all weedy cropping systems. From the weed free cropping systems, the minimum effective tillers were observed in intercropping of wheat with gobhi sarson (74.0) and these were found at par with African sarson, lentil and fenugreek. From the weedy cropping systems, the minimum count of tillers was found in intercropping of wheat with gobhi sarson weedy cropping system (59.3) which were found at par with intercropping of wheat with African sarson, lentil, and wheat weedy cropping system.

During the second year (2021-22), it was observed that the maximum effective tillers were found in the wheat weed free cropping system (85.3). The wheat weed free cropping system was observed statistically at par with intercropping of wheat with fennel & intercropping of wheat with dil seed weed free cropping system (Table 4.2.5). These cropping systems recorded significantly higher effective tillers than all weedy cropping systems. From the weed free cropping systems, the minimum effective tillers were observed in intercropping of wheat with gobhi sarson (75.3) and these were found at par with intercropping of wheat with African sarson. From the weedy cropping system, the minimum effective tillers were found in intercropping of wheat with gobhi sarson weedy cropping system (62.25) which was found at par with intercropping of wheat with African sarson, lentil and wheat weedy.

From the pooled data (2020-21 and 2021-22), the maximum numbers of effective tillers were found in the wheat weed free cropping system (85.0) which were significantly higher than all other cropping systems (Table 4.2.5). From the weed free cropping system, the minimum number of tillers were observed in intercropping of wheat with gobhi sarson (74.6) which was at par with African sarson and both intercropping systems recorded significantly less effective tillers than intercropping of wheat with lentil, fenugreek, fennel and dil seed. From the weedy cropping system, the number of effective tillers were found in intercropping of wheat with gobhi sarson (60.8) which were significantly lower than all other cropping systems. The infestation of *Phalaris minor* decreased the effective tillers significantly in different intercrops compared to weed free conditions. The highest reduction was observed in wheat (25.76%). The minimum percentage decrease was found in African sarson. Intercropping of wheat with gobhi sarson, lentil, fenugreek, fennel and dil seed weedy treatments also decreased the effective tillers by 18.49%, 16.68%, 17.80%, 18.68% and 18.31% respectively by weedy crop over weed free. This result was inconformity with Wasaya et al., (2013).

Table 4.2.5: Effective tillers in bed planted wheat as influenced by different intercrops

Treatments	Effective tillers/m row length			
	2020-21	2021-22	Pooled	Percent decrease over weed free
Wheat, weed free	84.8	85.3	85.0	25.76
Wheat, weedy	62.3	64.0	63.1	
Wheat+Gobhi sarson, weed free	74.0	75.3	74.6	18.49
Wheat+Gobhi sarson, weedy	59.3	62.3	60.8	
Wheat+African sarson, weed free	75.3	76.0	75.6	14.81
Wheat+African sarson, weedy	63.8	65.0	64.4	
Wheat+Lentil, weed free	77.3	79.8	78.5	16.68
Wheat+Lentil, weedy	65.0	65.8	65.4	
Wheat+Fenugreek, weed free	79.8	80.8	80.3	17.80
Wheat+Fenugreek, weedy	65.8	66.3	66.0	
Wheat+Fennel, weed free	83.0	84.0	83.5	18.68
Wheat+Fennel, weedy	67.3	68.5	67.9	
Wheat+Dil seed, weed free	81.5	82.3	81.9	18.31
Wheat+Dil seed, weedy	66.5	67.3	66.9	
CD at 5%	6.06	4.12	4.62	

4.3. Yield attributes

The yield of any crop depends upon the status of its yield attributing characters like spike length, pod length, 1000 grain weight, number of grains per spike/pod etc.

4.3.1 Spike length (cm)

Spike length is an important yield contributing character which is associated with the number of grains. Length of spike varies with type of crop or variety. In the first year (2020-21), among the different weed free treatments, the higher spike length was found in the wheat weed free (10.1 cm) followed by intercropping of wheat with fennel weed free treatment (9.8 cm), fenugreek (9.45cm) and dil seed weed free (9.45 cm) which were found at par among themselves and significantly these treatments were higher than all other treatments (Table 4.3.1). The spike length of wheat intercrop with fennel was found at par with wheat intercrop with dil seed and fenugreek and these crops produced significantly higher spike length than all other treatments. From the weed free treatments, the lower spike length was found in intercropping of wheat with gobhi sarson (8.18 cm) which was found at par with intercropping of wheat with African sarson and lentil. From the weedy treatments, the minimum spike length was found in intercropping of wheat with gobhi sarson (5.85 cm) which was found at par with intercropping of wheat with African sarson and wheat weedy treatment. Spike length of wheat in weed free treatments under all intercrops was significantly higher than weedy conditions for their respective intercrops.

In the second year (2021-22), among the different weed free treatments the higher spike length was found in the wheat weed free (12.15cm) followed by intercropping of wheat with fennel weed free treatment (10.23cm) (Table 4.3.1) which were significantly higher than all other intercropping treatments. The spike length of wheat intercropped with fennel was found at par with wheat intercropped with dil seed and fenugreek and it was significantly higher than all other treatments. From the weed free treatments, the lower spike length was also found in intercropping of wheat with gobhi sarson weed free (8.25cm) which was statistically at par with intercropping of wheat with African sarson. From the weedy treatments, significantly minimum spike length was found in intercropping of wheat with gobhi sarson (6.08) which was found at par with intercropping of wheat with African sarson and wheat weedy treatment. Infestations by *Phalaris minor* resulted in significant reduction of wheat spike length under weedy as compared to weed free conditions for respective intercrops.

On the basis of pooled data (2020-21 and 2021-22), the higher spike length was found in the wheat weed free (11.14cm) followed by intercropping of wheat with fennel weed free treatment (10.63cm) which were significantly higher than all other treatments (Table 4.3.1). Among the intercropping systems, significantly higher spike length of wheat was found in intercrop wheat with fennel. From weed free treatments, the lower spike length was found in intercropping of wheat with gobhi sarson (8.21cm). Intercropping of wheat with gobhi sarson was statistically at par with intercropping of wheat with African sarson. From the weedy treatments, the minimum spike length was found in intercropping of wheat with gobhi sarson weed free treatment (5.96cm) which was statistically at par with intercropping of wheat with African sarson and wheat weedy treatment which was significantly less than other intercropping systems. The spike length of wheat intercropped with fenugreek was found at par with fennel and dil seed both under weedy and weed free conditions. There was significant reduction in spike length of wheat intercropped with different crops under weedy conditions as compared to weed free situations for their respective intercrop. The *Phalaris minor* decreased the spike length of wheat differently in different intercrops. The highest reduction in wheat spike length was observed in wheat weedy (43.35%). The minimum percentage decrease was found in lentil crop 23.58%. Intercropping of wheat with gobhi sarson, African sarson, fenugreek, fennel and dil seed weedy treatment also decreased the spike length as 27.40%, 27.85%, 27.20%, 28.34% and 26.97% respectively by weedy crop over weed free. These results were in conformity with Naeem *et al*., (2012).

The maximum spike length of wheat was found when wheat was sown alone and minimum was found when it was sown with gobhi sarson or African sarson. The reduction in the spike length might be due to aggressive growing nature of gobhi sarson and African sarson and these crops competed with wheat for nutrients. All spice crops intercropping resulted in comparatively less reduction of spike length of wheat than other crops.

Table 4.3.1: Spike length of wheat (cm) as influenced by different intercrops sown in bed planted wheat.

	Spike length(cm)			
Treatments	**2020-21**	**2021-22**	**Pooled**	**Percent decrease over weed free**
Wheat, weed free	10.13	12.15	11.14	43.35
Wheat, Weedy	6.25	6.38	6.31	
Wheat+ Gobi sarson, weed free	8.18	8.25	8.21	27.40
Wheat + Gobi sarson, Weedy	5.85	6.08	5.96	
Wheat +African sarson, weed free	8.43	8.73	8.58	27.85
Wheat + African sarson, Weedy	6.03	6.35	6.19	
Wheat +Lentil, weed free	8.88	9.18	9.03	23.58
Wheat +Lentil, Weedy	6.83	6.98	6.90	
Wheat +Fennugreek, weed free	9.33	9.93	9.63	27.20
Wheat +Fennugreek, Weedy	6.95	7.08	7.01	
Wheat +Fennel, weed free	9.83	10.63	10.23	28.34
Wheat +Fennel, Weedy	7.23	7.43	7.33	
Wheat +Dil seed, weed free	9.45	10.05	9.75	26.97
Wheat +Dil seed, Weedy	7.09	7.15	7.12	
CD at 5%	0.89	0.73	0.43	

4.3.2 Pod length (cm) of intercrops

Pod length is yield contributing parameter and it is associated with the number of grains. Increase in the length of pod would increases the yield. During first year (2020-21), the maximum pod length was found in fenugreek weed free (7.09cm) followed by fenugreek weedy (6.10cm) (Table 4.3.2). All weed free treatment of different intercrops significantly increased pod length than weedy treatment. The pod length of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and infestation of *Phalaris minor* decreased 26.31% pod length in gobhi sarson weedy treatment as compared with gobhi sarson weed free treatment. Similarly *P.minor* infestations had decreased 20.9%, 38.52% and 13.96% pod length of intercrops viz. African sarson, lentil and fenugreek respectively compared to their respective weed free treatments.

In the second year (2021-22), the higher pod length was found in fenugreek intercropped in wheat under weed free (7.43cm) followed by fenugreek weedy (6.78cm) which were significantly more than all other intercrops (Table 4.3.2). All weed free treatment of different intercrops significantly increased pod length than weedy treatment. The pod length of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and infestation of *Phalaris minor* decreased 3.34% pod length in gobhi sarson weedy treatment as compared with gobhi sarson weed free treatment. Similarly *P.minor* infestations had decreased 18.18%, 25.49% and 8.74% pod length of intercrops viz. African sarson, lentil and fenugreek respectively compared to their respective weed free treatments.

On the basis of pooled data (2020-21 and 2021-22), the maximum pod length was found fenugreek weed free (7.26cm) followed by fenugreek weedy (6.44cm) which were significantly more than all other intercrops (Table 4.3.2). All weed free treatment of different intercrops significantly increased pod length than weedy treatment. The pod length of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment and infestation of *Phalaris minor* decreased 28.96% pod length in gobhi sarson weedy treatment as compared with gobhi sarson weed free treatment. Similarly *P.minor* infestations had decreased 19.12%, 31.85% and 11.29% pod length of intercrops viz. African sarson, lentil and fenugreek respectively compared to their respective weed free treatments. This result was inconformity with Wasaya *et al*., (2013).

Table 4.3.2: Pod length of intercrops (cm) in bed planted wheat

Treatments	Pod length(cm)			
	2020-21	2021-22	Pooled	Percent decrease over weed free
Wheat+ Gobi sarson, weed free	5.13	5.71	5.42	28.96
Wheat+ Gobi sarson, weedy	3.78	3.92	3.85	
Wheat+African sarson, weed free	4.08	4.18	4.13	19.12
Wheat+ African sarson, weedy	3.26	3.42	3.34	
Wheat+Lentil, weed free	2.44	2.51	2.48	31.85
Wheat+Lentil, weedy	1.5	1.87	1.69	
Wheat+Fennugreek, weed free	7.09	7.43	7.26	11.29
Wheat+Fennugreek, weedy	6.1	6.78	6.44	
CD at 5%	0.1	0.1	0.20	

4.3.3 Number of grains per spike of wheat

Numbers of grains per spike were recorded after harvesting wheat crop. Generally, number of grains per spike depends on agronomic & cultural practices adopted during experimentation. Treatments having maximum number of grains per spike lead to enhance the yield of wheat. The data relevant to number of grains per spike was shown in Table 4.3.3. During the first year (2020-21), it was observed that the higher number of grains per spike were found in the wheat weed free cropping system (44.5) which was statistically at par with intercropping of wheat with fennel weed free cropping system. The intercropping of wheat with lentil weed free cropping system recorded at par with intercropping of wheat with fenugreek weed free cropping system. These cropping systems produced significantly more number of grains/spike than all weedy cropping systems. From the weed free cropping systems, the less numbers of grains per spike were observed in intercropping of wheat with gobhi sarson (30.78) which was found at par with intercropping of wheat with African sarson. Also among the weedy cropping system, the less numbers of grains per spike were found in intercropping of wheat with gobhi sarson (30.78) which was found at par with intercropping of wheat with African sarson and wheat weedy.

During the second year (2021-22), it was observed that the significantly more numbers of grains per spike were found in the wheat weed free cropping system (49.75) (Table 4.3.3). The intercropping of wheat with fennel remained statistically at par with intercropping of wheat with dil seed under weed free cropping system. These cropping systems were significantly higher than all weedy cropping systems. The intercropping of wheat with lentil weed free cropping system remained statistically at par with intercropping of wheat fenugreek. From the weed free cropping systems, the less numbers of grains per spike were found in intercropping of wheat with gobhi sarson (39.9) which was found at par with intercropping of wheat with African sarson. Also, the weedy cropping systems, the minimum numbers of grains per spike were found in intercropping of wheat with gobhi sarson weedy (32.5) which was found at par with intercropping of wheat with African sarson, lentil and wheat weedy.

From the pooled data (2020-21 and 2021-22), the higher numbers of grains per spike were found in the wheat weed free cropping system (47.13) (Table 4.3.3). The intercropping of wheat with fennel was at par with intercropping of wheat with dil seed cropping system and these cropping systems were significantly higher than all weedy cropping systems. From the weed free cropping system, the minimum numbers of grains per spike were observed in intercropping of wheat with gobhi sarson (38.9) and this cropping system recorded significantly lower number of grains per spike than all weed free cropping system. From the weedy cropping system, the less numbers of grains per spike were found in intercropping of wheat with gobhi sarson (31.63) which was found at par with intercropping of wheat with African sarson and wheat weedy cropping system. The *Phalaris minor* decreased the number of grains per spike differently in different wheat intercrops. The highest reduction in number of grains were observed in wheat weedy (32.48%). Intercropping of wheat with gobhi sarson, African sarson, lentil, fenugreek, fennel and dil seed weedy treatment also decreased the number of grains by 18.76%, 18.95%, 19.80%, 21.37%, 21.97% and 21.79% respectively by weedy crop over weed free. This result was inconformity with Wasaya *et al*., (2013).

Table 4.3.3: Number of grains per spike in bed planted wheat as influenced by different intercrops

Treatments	Number of grains per spike			
	2020-21	2021-22	Pooled	Percent decrease over weed free
Wheat, weed free	44.5	49.8	47.1	32.48
Wheat, Weedy	31.1	32.5	31.8	
Wheat+Gobhi sarson, weed free	38.1	39.8	38.9	18.76
Wheat+Gobhi sarson, Weedy	30.8	32.5	31.6	
Wheat+African sarson, weed free	39.3	40.8	40.1	18.95
Wheat+African sarson, Weedy	31.7	33.4	32.5	
Wheat+Lentil, weed free	40.7	42.1	41.4	19.80
Wheat+Lentil, Weedy	32.0	34.4	33.2	
Wheat+Fenugreek, weed free	41.6	45.4	43.5	21.37
Wheat+Fenugreek, Weedy	33.5	34.8	34.2	
Wheat+Fennel, weed free	43.4	47.6	45.5	21.97
Wheat+Fennel, Weedy	34.2	36.7	35.5	
Wheat+Dil seed, weed free	42.9	46.1	44.5	21.79
Wheat+Dil seed, Weedy	33.8	35.8	34.8	
CD at 5%	1.23	2.11	1.05	

4.3.4 Test weight (1000 grain weight) (g)

Grain weight depends upon the size and development of grain. Grain weight is a function of various production factors which are influenced by various environment conditions prevailing at grain filling periods. During 2020-21, it had been observed that the maximum test weight was found in the wheat weed free cropping system (43.1 gm). It was found at par with intercropping of wheat with fennel and dil seed weed free cropping system (Table 4.3.4). These cropping systems recorded significantly higher test weight than all weedy cropping systems. From the weed free cropping systems, the minimum test weight was observed in intercropping of wheat with gobhi sarson (39.1gm) and it was found at par with intercropping of wheat with African sarson and lentil. From the weedy cropping systems, the minimum test weight was found in intercropping of wheat with gobhi sarson (34.9) which was found at par with intercropping of wheat with African sarson, lentil and wheat weedy cropping system.

In the second year (2021-22), it was observed that the maximum test weight was found in the wheat weed free cropping system (44.8 gm). The weed free was recorded at par with intercropping of wheat with fennel and dil seed weed free cropping system (Table 4.3.4). These cropping systems gave significantly higher test weight than all other weedy cropping systems. From the weed free cropping systems, the minimum test weight was observed in intercropping of wheat with gobhi sarson (40.1) which was found at par with intercropping of wheat with African sarson, lentil and fenugreek. From the weedy cropping systems, the minimum test weight was found in intercropping of wheat with gobhi sarson (35.7 gm) which was found at par with intercropping of wheat with African sarson, lentil, fenugreek and wheat weedy cropping system.
From the pooled data of 2020-21 and 2021-22, it can be concluded that, the maximum test weight was found in the wheat weed free cropping system (43.9 gm). It was significantly more than all other cropping systems (Table 4.3.4). From the weed free cropping system, the minimum test weight was observed in intercropping of wheat with gobhi sarson weed free cropping system (39.54 gm) and it was found at par with African sarson weed free cropping system. From the weedy cropping system, the minimum test weight was found in intercropping of wheat with gobhi sarson weedy cropping system (35.3 gm) which was found at par with intercropping of wheat with African sarson and wheat weedy cropping system. The *Phalaris minor* decreased the wheat test weight differently in different intercrops. The highest reduction in wheat test weight was observed in wheat weedy (19.36%). Intercropping of wheat with gobhi sarson, African sarson, lentil,

fenugreek, fennel and dil seed weedy treatment also decreased the test weight as 10.63%, 10.5%, 10.81%, 10.21%, 12.24% and 12.6% respectively by weedy crop over weed free.

All the yield attributes of bed planted wheat like spike length, number of grains / spike and test weight were found better when fennel and dil seed were intercropped as compared to pure wheat which may be due to their less competitive effects. On the other hand, all these parameters were on the lower side when gobhi sarson and African sarson was intercropped due to their more height which had shading effect on wheat crop.

Table 4.3.4: Test weight (g) of bed planted wheat as influenced by different intercrops

Treatments	Test weight of wheat grains (gm)			
	2020-21	2021-22	Pooled	Percent decrease over weed free
Wheat, weed free	43.1	44.8	43.9	19.36
Wheat, weedy	35.0	35.8	35.4	
Wheat+Gobhi sarson, weed free	39.1	40.1	39.5	10.63
Wheat+Gobhi sarson, weedy	34.9	35.7	35.3	
Wheat+African sarson, weed free	39.2	40.9	40.0	10.5
Wheat+African sarson, weedy	35.4	36.2	35.8	
Wheat+Lentil, weed free	40.4	41.1	40.7	10.81
Wheat+Lentil, weedy	36.1	36.6	36.3	
Wheat+Fenugreek, weed free	40.8	41.4	41.1	10.21
Wheat+Fenugreek, weedy	36.7	37.0	36.9	
Wheat+Fennel, weed free	42.8	43.9	43.3	12.24
Wheat+Fennel, weedy	37.8	38.2	38.0	
Wheat+Dil seed, weed free	42.2	43.3	42.7	12.66
Wheat+Dil seed, weedy	37.1	37.5	37.29	
CD at 5%	1.43	1.44	0.38	

4.3.5 Test weight of intercrops (gm)

During 2020-21, it has been observed that the maximum test weight was found in the lentil weed free cropping system (22.7 gm) which was significantly higher than all tried crops and was followed by lentil weedy cropping system (18.8 gm) (Table 4.3.5). From the weed free cropping systems, the minimum test weight was observed in intercropping of wheat with African sarson (4.05gm) which was significantly lower than all tried crops under weed free cropping systems. From the weedy cropping systems, the minimum test weight was found in intercropping of wheat with African sarson (2.5gm) which was significantly lower than the test weight of all tried crops in different cropping systems.

In the second year (2021-22), it was observed that the maximum test weight was found in the lentil weed free cropping system (24.66 gm) which was significantly higher than all tried crops which was followed by lentil weedy cropping system (19.48 gm) (Table 4.3.5). These cropping systems recorded significantly higher test weight than all crops under weedy cropping systems. From the weed free cropping systems, the minimum test weight was observed in intercropping of wheat with African sarson (4.46gm) which was found to be significantly lower than all tried weed free cropping systems. From the weedy cropping systems, the minimum test weight was found in intercropping of wheat with African sarson (2.97gm) which was significantly lower than all tried crops.

From the pooled data of 2020-21 and 2021-22 it can be concluded that, the maximum test weight was found in the lentil weed free cropping system (23.57 gm) which was significantly higher than all tried crops and was followed by lentil weedy cropping system (19.14gm) (Table 4.3.5). The test weight of lentil was significantly higher than all crops under weedy and weed. From the weed free cropping systems, the minimum test weight was observed in intercropping of wheat with African sarson (4.26gm) which was recorded significantly lower than all tried crops under weed free cropping system. From the weedy cropping systems, the minimum test weight was found in intercropping of wheat with African sarson (2.74 gm) which was significantly lower than all tried crops in different cropping systems. The *Phalaris minor* decreased the test weight differently in different intercrops. The highest reduction in test weight was observed in African sarson (35.68%) followed by gobhi sarson, 23.95%. The minimum percentage decrease was found in lentil crop (18.79%). Intercropping of wheat with fennel and dil seed weedy treatment also decreased the test weight by 22.66% and 23.24% respectively over weed free.

The test weight of different crops used as intercrop in wheat varied a lot which may be due to their genetic characteristics because size and density of seeds varies from one crop to other crop. Among the tried crops, the seeds of lentil are bold and dense and hence its test weight was very high. The minimum test weight was of African sarson, gobhi sarson and dil seed. The test weight of fennel and fenugreek was intermediate. These are genetic differences only.

Table 4.3.5: Test weight (g) of intercrops grown in bed planted wheat.

Treatments	Test weight (gm)			
	2020-21	2021-22	Pooled	Percent decrease over weed free
Wheat+Gobhi sarson, weed free	4.52	5.07	4.80	23.95
Wheat+Gobhi sarson, Weedy	3.37	3.93	3.65	
Wheat+African sarson, weed free	4.05	4.46	4.26	35.68
Wheat+African sarson, Weedy	2.5	2.97	2.74	
Wheat+Lentil, weed free	22.47	24.66	23.57	18.79
Wheat+Lentil, weedy	18.8	19.48	19.14	
Wheat+Fenugreek, weed free	8.62	10.30	9.46	19.87
Wheat+Fenugreek, weedy	7.01	8.15	7.58	
Wheat+Fennel, weed free	8.08	8.41	8.25	22.66
Wheat+Fennel, weedy	6.12	6.64	6.38	
Wheat+Dil seed, weed free	5.22	5.62	5.42	23.24
Wheat+Dil seed, weedy	4.12	4.19	4.16	
CD at 5%	0.27	0.20	0.53	

4.3.6 Intercrop yield (q/ha)

Intercrop yield leads to economics of field crops which depends on quantity of product and its market rates. The intercrop yield data ars presented in Table 4.3.6 and graphically shown in Fig.4.1.6. Intercrop yield of different intercropping systems, reflect the economic viability of a specific system as well as its production efficiency. In the first year (2020-21), it was observed that maximum yield was found in gobhi sarson weed free treatment (7.52 q/ha) followed by African sarson weed free treatment (5.79 q/ha) and both these treatments produced significantly more yield than the yield of other intercrops (Table 4.3.6). All weed free treatments were found significantly better than all weedy treatments for their respective crops. From the mustard crop, the highest yield was found in weed free gobhi sarson which was 23% more than African sarson weed free. From the medicinal crops, the highest yield was found in weed free dil seed which was significantly higher than fenugreek and was at par with weed free fennel crop. The yield of intercropped dil seed was found at par with intercropped lentil in wheat under weed free. From the weedy treatments, the lowest yield was found in intercropping of fenugreek weedy treatment. The intercropping of fenugreek was recorded at par with dil seed weedy and found significantly lower than all other treatments.

In the second year (2021-22), the higher yield was found in gobhi sarson weed free treatment (7.79 q/ha) followed by African sarson weed free treatment (6.00 q/ha) (Table 4.3.6). Significantly more seed yield was found in gobhi sarson weed freeand it was more than seed yield of all other intercrops under weed free. All weed free treatments gave significantly higher seed yield than all weedy treatments of respective intercrops. From the mustard crop, the highest yield was found in weed free gobhi sarson which was 22.97% more than African sarson weed free. From the medicinal crops, the highest yield was found in weed free dil seed which was found at par with fennel weed free and was significantly higher from fenugreek. The second highest yield was found in weed free fennel crop which was at par with dil seed. The intercropping with lentil was statistically at par with intercropping with dil seed weed free. From the weedy treatments, the lowest yield was found in intercropping of wheat with fenugreek weedy treatment. It was significantly lower than all other treatments.

From the pooled table (2020-21 and 2021-22), the maximum yield was found in intercropping with gobhi sarson weed free treatment (7.65 q/ha) followed by intercropping with African sarson weed free treatment (5.90 q/ha) (Table 4.3.6). The intercropping with gobhi sarson weed free significantly produced higher seed yield than all other intercrops. The seed yield of all weed free treatments was significantly higher than all weedy treatments among their respective crops. From the mustard crop, the highest yield was found in weed free gobhi sarson which was 22.87% more than African sarson weed free. From the medicinal crops, the highest yield was found in weed free dil seed which was statistically at par with intercropping of wheat with fennel weed free and was significantly more than fenugreek. The intercropping of wheat with lentil was found at par with intercropping of wheat with dil seed and fennel weed free. From the weedy treatments, the lowest yield was found in intercropping of wheat with fenugreek which was significantly lower than all other treatments.

The maximum intercrop yield was found in intercropping of wheat with gobhi sarson weed free treatment. This might be due to high genetic potential of gobhi sarson per unit area. Although the yield potential of fennel, dil seed and fenugreek are low but their market rates are high resulting in high net income of the farmer. The *Phalaris minor* decreased the intercrop yield differently in different intercrops. The highest reduction in yield due to *Phalaris minor* infestations was observed in gobhi sarson (44.44%). The minimum percentage decrease was found in lentil crop 26.64%. Intercropping of wheat with African sarson, fenugreek, fennel and dil seed decreased the yield by 29.54%, 29.79%, 33.22%, 38.39% respectively under weedy crop over weed free.

Table 4.3.6: Yield of different intercrops (q/ha) raised in bed planted wheat

	Intercrop yield (q/ha)			
Treatments	**2020-21**	**2021-22**	**Pooled**	**Percent decrease over weed free**
Wheat+ Gobi sarson, weed free	7.52	7.78	7.65	44.44
Wheat+ Gobi sarson, weedy	4.16	4.33	4.25	
Wheat+African sarson, weed free	5.79	6.00	5.89	29.54
Wheat+ African sarson, weedy	4.49	3.81	4.15	
Wheat+Lentil, weed free	3.28	3.40	3.34	26.64
Wheat+Lentil, Weedy	2.48	2.43	2.45	
Wheat+Fennugreek, weed free	2.40	2.51	2.45	29.79
Wheat+Fennugreek, weedy	1.70	1.74	1.72	
Wheat+Fennel, weed free	3.11	3.33	3.22	33.22
Wheat+Fennel, Weedy	2.12	2.18	2.15	
Wheat+Dil seed, weed free	3.34	3.39	3.36	38.39
Wheat+Dil seed, Weedy	2.03	2.12	2.07	
CD at 5%	0.65	0.32	0.19	

4.3.7 Grain yield of wheat (q/ha)

The grain yield is the most important factor for the agricultural net profit. The data pertaining to the effect of different intercrops in bed planted wheat on grain yield is given in the Table 4.3.7 and graphically shown in Fig. 4.1.6. Weed free treatments for different intercrops showed significantly higher wheat grain yield than weedy treatment for their respective crops. Among the different weed free treatments, the higher grain yield was found in the wheat weed free (63.63 q/ha) during 2020-21. In the first year, the grain yield of wheat in intercropping of medicinal crops under weed free conditions (fennel and dil seeds) were found at par with wheat weed free conditions (the standard treatment). The grain yield of wheat in intercropping of wheat with lentil, fenugreek, gobhi sarson and African sarson under weed free situations was significantly lower than wheat weed free. In the weedy treatments, the lowest grain yield was found in intercropping of wheat with gobhi sarson weedy (36.04 q/ha) which was significantly less than wheat weed free treatment. In the first year, the intercropping of wheat with gobhi sarson weedy was found at par with wheat weedy treatment and wheat with African sarson weedy. The other weedy treatments like wheat+lentil, wheat+fennel, wheat+fenugreek and wheat+dil seed recorded significantly more grain yield of wheat than intercropping of wheat with gobhi sarson.

During the second year (2021-22), the yield level of different crops were slightly higher than first year which may be due to more favourable conditions. The highest yield was found in wheat weed free treatment (65.91 q/ha). This cropping system was recorded at par with intercropping of wheat with fennel weed free (63.95 q/ha) (Table 4.3.7). The intercropping of wheat with fenugreek and dil seed weed free treatment were found at par with wheat weed free treatment with respect to wheat grain yield. The intercropping of wheat with gobhi sarson, African sarson and lentil under weed free conditions gave significantly less grain yield of wheat than wheat weed free treatment. The lowest yield was found in intercropping of wheat with gobhi sarson weedy treatment (34.95 q/ha) during 2021-22 which was found at par with wheat weedy treatment, wheat+African sarson weedy. The grain yield of wheat+lentil, wheat+fenugreek, wheat+fennel and wheat+ dil seed was significantly higher than intercropping of wheat with gobhi sarson weedy treatment. All weedy treatments produced significantly lower wheat grain yield than their respective weed free treatments.

It was concluded from the pooled data (2020-21 and 2021-22) that, the highest wheat yield was found in weed free treatment (64.77 q/ha) followed by intercropping of wheat with fennel and dil seed under weed free. All these cropping systems were significantly more than all other treatments under weedy and weed free conditions whereas these were at par among each other (Table 4.3.7). The lowest yield was found in the treatment of intercropping wheat with gobhi sarson weedy (35.49 q/ha) which was found at par with wheat weedy and both these treatments gave significantly less wheat grain yield than wheat intercropped with all other crops under weedy and weed free situations. All weed free treatments gave significantly higher seed yield over their respective intercrops under weedy conditions. The treatment of intercropping of wheat and Gobhi sarson weedy was recorded at par with treatment of wheat weedy. The gobhi sarson intercropping significantly reduced wheat grain yield than all other intercrops under weedy conditions. The intercropping treatments of weed free with gobhi sarson, African sarson, lentil, fenugreek and dil seed gave significantly lower yield than wheat with weed free treatment. However, whet grain yield with fennel was found at par with wheat weed free. The *Phalaris minor* decreased the wheat yield differently in different intercrops. The maximum reduction in wheat yield was observed in wheat weedy (44.14%), followed by gobhi sarson, 36.06%. The minimum percentage decrease was found in lentil crop (21.63%). Intercropping of wheat with African sarson, fenugreek, fennel and dil seed decreased the yield by 32.76%, 25.48%, 25.56%, 23.71% respectively by weedy crop over weed free. Wasaya *et al*., (2013) and Riaz *et al*. (2022) also reported the reduction in intercropped wheat yield due to suppressive effect of intercrops on the yield of the base crop.

Reduction in grain yield of main crop may be due to more inter and intra specific competition of the component crops with main crop for different growth factors i.e., moisture, nutrient, space, solar radiation etc. Brassica crops due to their more height are better competitor for all growth factors, thus reduce more yield of main crop (wheat). On the other hand, lentil, dil seed, fenugreek and fennel are less competitor and hence reduction in wheat grain yields are comparatively less than brassisca crops. Less reduction in wheat grain yield by the medicinal crops as compared to Brassica crops may be due to the release of allelochemicals by the former crops. The intercropping of wheat with lentil reduced the wheat grain yield and it was minimum (21.63%) which was followed by dil seed, fennel and fenugreek as the plant height of thse intercrops was less and all the crops enjoyed the benefits of open space between the beds.

Table: 4.3.7: Yield of wheat (q/ha) in bed planted technology as influenced by different intercrops

	Wheat yield (q/ha)			
Treatments	**2020-21**	**2021-22**	**Pooled**	**Percent decrease over weed free**
Wheat, weed free	63.64	65.91	64.78	44.14
Wheat, Weedy	36.31	36.05	36.18	
Wheat+ Gobi sarson, weed free	54.24	56.78	55.51	36.06
Wheat+ Gobi sarson, weedy	36.04	34.95	35.49	
Wheat+African sarson, weed free	55.83	57.23	56.53	32.76
Wheat+ African sarson, weedy	38.10	37.93	38.01	
Wheat+Lentil, weed free	56.66	58.36	57.51	21.63
Wheat+Lentil, Weedy	44.65	45.49	45.07	
Wheat+Fennugreek, weed free	57.91	59.25	58.58	25.48
Wheat+Fennugreek, Weedy	43.39	43.91	43.65	
Wheat+Fennel, weed free	62.09	63.95	63.02	25.56
Wheat+Fennel, Weedy	46.33	47.50	46.91	
Wheat+Dil seed, weed free	59.46	61.23	60.34	23.71
Wheat+Dil seed, Weedy	44.86	47.19	46.03	
CD at 5%	4.061	7.20	3.91	

4.3.8 Wheat equivalent yield (q/ha)

The yield of different intercrops was converted into wheat equivalent yield in order to find out the overall impact of treatments in terms of comparable yield data. The converted intercrops yield was then added to the actual yield of wheat in the respective year. The wheat equivalent yield expresses the total yield (productivity) for the wheat-intercrop system. Wheat equivalent yield is the yield of wheat plus yield of intercrops expresses in terms of wheat equivalent yield (market value of intercrops divided by rate of wheat interms of Rs./quintal. The data related to wheat equivalent yield is described in Table 4.3.8 and graphically shown in Fig. 4.1.6. In the first year (2020-21), the highest wheat equivalent yield was found in intercropping of wheat along with dil seed weed free (81.44 q/ha) followed by intercropping of wheat with fennel crop weed free (79.42 q/ha) and both these intercropping systems significantly increased wheat equivalent yield than wheat alone-the standard practice of the farmers (Table 4.3.8). The intercropping of wheat with dil seed was found at par with intercropping of wheat with fennel crop weed free. The intercropping of wheat with lentil weed free was found at par with intercropping of wheat with fenugreek weed free and both these intercrops gave at par with sole wheat crop under weed free conditions. The weed free treatment of wheat+gobhi sarson was recorded at par with African sarson weed free and both these treatments gave significantly higher wheat equivalent yield than wheat weed free. All weed free treatments recorded significantly more yield than respective weedy treatments. The lowest wheat equivalent yield was found in wheat weedy treatment (36.31 q/ha) which was significantly lower than all other weedy intercropping treatments. From the intercropping treatments, the lowest wheat equivalent yield was found in intercropping of wheat with gobhi sarson weedy treatment. It was significantly higher than wheat weedy treatment and statistically at par with intercropping of wheat with African sarson, lentil, and fenugreek weedy treatment. The lowest wheat equivalent yield was found in wheat weedy treatment which was significantly lower than all other weedy intercropping treatments. From the intercropping treatments, the lowest wheat equivalent yield was found in intercropping of wheat with gobhi sarson weedy treatment which was significantly higher than wheat weedy treatment and statistically at par with intercropping of wheat with African sarson, lentil, and fenugreek weedy treatment.

In the second year (2021-22), the highest wheat equivalent yield was found in dill seed weed free (84.99 q/ha) followed by intercropping of wheat with fennel weed free treatment (82.47

q/ha) and both these treatments gave significantly more WEY (wheat equivalent yield) than wheat as sole (Table 4.3.8). The intercropping of wheat with dill seed weed free was found at par with intercropping of wheat with fennel weed free treatment. The intercropping of wheat with gobhi sarson weed free gave significantly high wheat equivalent yield as compare to wheat weed free, wheat with African sarson, wheat with lentil and wheat with fenugreek weed free treatments. The intercropping of wheat with African sarson weed free was found at par with intercropping of wheat with lentil and fenugreek weed free treatment. The lowest yield was found in wheat weedy treatment (36.05 q/ha) which was significantly lower than all weedy and weed free intercropping treatments indicating that all intercrops helped to smother *Phalaris minor*. The intercropping of wheat with gobhi sarson weedy treatment was found at par with intercropping of wheat with African sarson and wheat+ fenugreek weedy treatment. The intercropping of wheat with lentil weedy treatment gave significantly more wheat equivalent yield than wheat weedy, wheat+gobhi sarson, wheat+African sarson and wheat+fenugreek. The intercropping of wheat with fennel was found at par with intercropping of wheat with dil seed. All the weed free treatments gave significantly more WEY (wheat equivalent yield) than weedy treatments of their respective crops.

From the pooled data, it may be concluded that highest wheat equivalent yield was found in dil seed weed free (83.22 q/ha) followed by intercropping of wheat with fennel weed free treatment (80.95q/ha) and both these intercropping systems recorded significantly more wheat equivalent yield than wheat alone (Table 4.3.8). All the intercrops sown in wheat under weed free treatments had significant greater value of wheat equivalent yield than wheat weed free treatment except lentil. The intercropping of wheat with lentil weed free treatment was found at par with intercropping of wheat with fenugreek. Both the mustard crop weed free treatment gave significantly higher wheat equivalent yield than lentil and fenugreek weed free intercropping systems. The lowest yield was found in wheat weedy treatment (36.18 q/ha) which was significantly lower than wheat equivalent yield of all intercrops under weedy and weed free conditions. The intercropping of wheat with fennel weedy was statistically at par with intercropping of wheat with dil seed weedy with respect to wheat equivalent yield. Both the mustard crop under weedy treatments gave significantly lower wheat equivalent yield than lentil and fenugreek. All weedy intercrop treatments gave significantly morer wheat equivalent yield than wheat weedy treatment. The highest reduction in WEY was observed in wheat alone in which, 44.14% yield was reduced. It was followed by Gobhi sarson, in which 38.12% yield was reduced.

The lowest percentage decrease was found in lentil crop (22.31%). Intercropping of wheat with African sarson, fenugreek, fennel and dil seed weedy treatment also decreased the wheat equivalent yield by 32.11%, 26.04%, 28.99%, 30.28% respectively over their weed free treatments (Wasaya *et al*., (2013).

Wheat equivalent yield was calculated by multiplying the yield of itercrop with its market value and then divided by rate of wheat in terms of Rs./quintal It can be concluded from two years data that fennel and dil seed increased wheat equivalent yield indicating their more suitability as intercrop in wheat as these crops showed less adverse effect on wheat growth due to their syngeristic effect. The profit of farmer can be increased by intercropping of dil seed or fennel in the furrows of bed planted wheat as compared to cultivation of sole bed planted wheat. In this system of wheat planting, there is sufficient space in between two rows of wheat sown on beds i.e., space of furrows is vacant which can be utilized for growing of suitable intercrops in order to increase the profitability of the farmers. These crops were followed by gobhi sarson and African sarson as WEY(wheat equivalent yield) of both these crops was also significantly higher than that of pure wheat. Intercropping of fenugreek and lentil do not increased WEY(wheat equivalent yield) as compared to alone wheat. The all medicinal crops gave more wheat equivalent yield as compared to sole crop of wheat. The wheat equivalent yield was significantly higher in intercropping of dil seed and fennel than pure weed free wheat which may be due to high market price of these medicinal crops which increased wheat equivalent yield.

Table 4.3.8: Wheat equivalent yield (q/ha) of different intercrops raised in bed planting system

	Wheat equivalent yield (q/ha)			
Treatments	**2020-21**	**2021-22**	**Pooled**	**Percent decrease over weed free**
Wheat, weed free	63.64	65.91	64.78	44.14
Wheat, Weedy	36.31	36.05	36.18	
Wheat+ Gobi sarson, weed free	71.94	75.09	73.52	38.12
Wheat+ Gobi sarson, weedy	45.83	45.15	45.49	
Wheat+African sarson, weed free	69.45	71.36	70.40	32.11
Wheat+ African sarson, weedy	48.67	46.90	47.79	
Wheat+Lentil, weed free	65.12	67.14	66.13	22.31
Wheat+Lentil, Weedy	51.05	51.69	51.37	
Wheat+Fennugreek, weed free	65.93	67.64	66.78	26.04
Wheat+Fennugreek, weedy	49.06	49.71	49.39	
Wheat+Fennel, weed free	79.42	82.47	80.95	28.99
Wheat+Fennel, Weedy	58.13	56.83	57.48	
Wheat+Dil seed, weed free	81.44	84.99	83.22	30.28
Wheat+ Dil seed, Weedy	58.20	57.84	58.02	
CD at 5%	4.08	6.34	4.46	

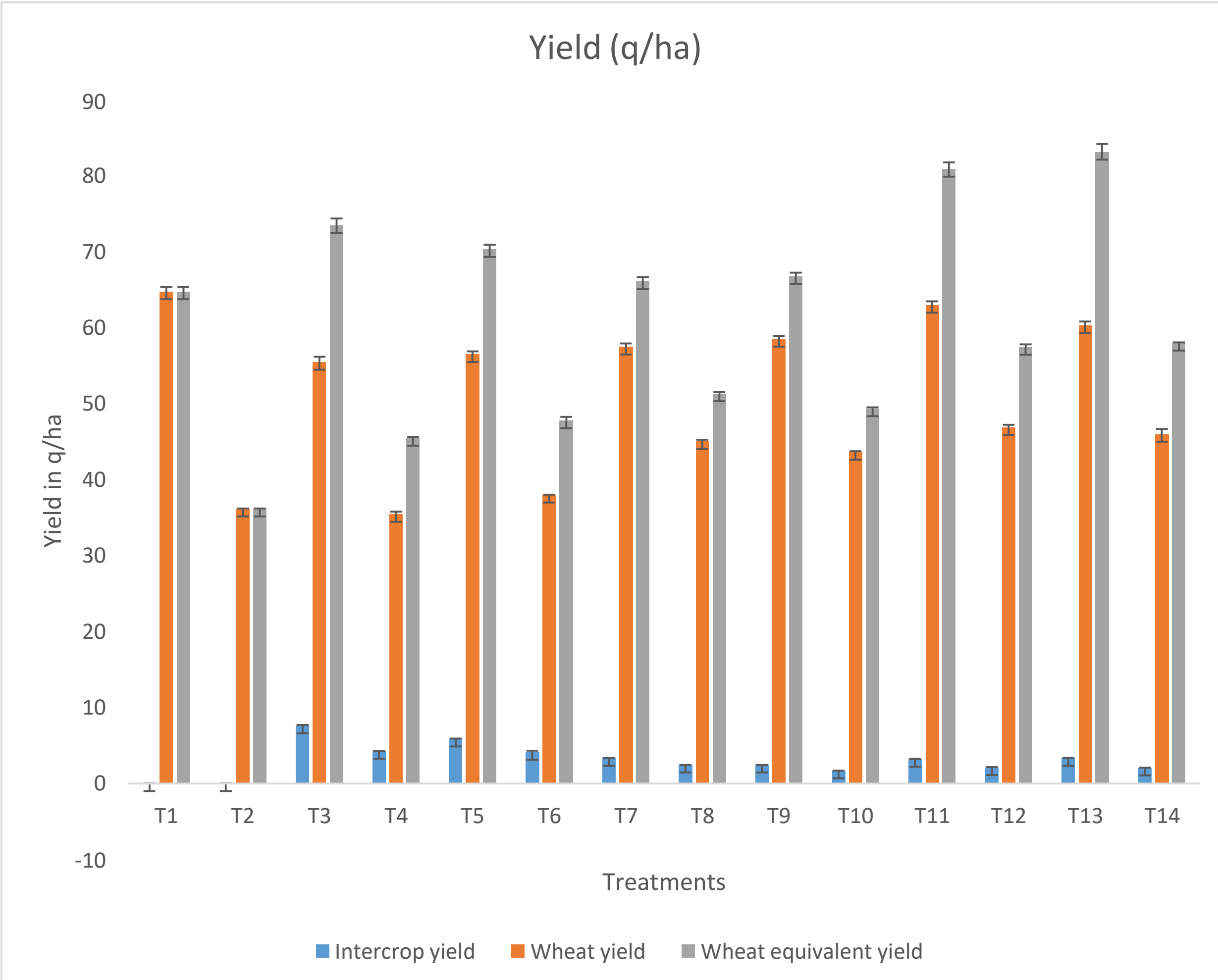


Fig.4.1.6: Intercrop yield, wheat yield and wheat equivalent yield (q/ha) of different intercrops raised in bed planting system

Note: T1-Wheat weed free, T2-Wheat weedy, T3-Wheat+Gobhi sarson weed free, T4-Wheat+Gobhi sarson weedy, T5-Wheat+African sarson weed free, T6-Wheat+African sarson weedy, T7-Wheat+Lentil weed free, T8-Wheat+Lentil weedy, T9-Wheat+Fenugreek weed free, T10-Wheat+Fenugreek weedy, T11-Wheat+Fennel weed free, T12-Wheat+Fennel weedy, T13-Wheat+Dil seed weed free, T14-Wheat+dil seed weedy

4.3.9 Straw yield (q/ha)

It is major component of total biological yield. Wheat straw yield is used for dry feed of cattle, in paper industry and mushroom cultivation etc. The data relating to straw yield has been shown in Table 4.3.9. During first year (2020-21), the wheat weed free showed significantly higher straw yield of wheat 85.21q/ha. From the weed free cropping systems, the least straw yield was found in intercropping of wheat with gobhi sarson (71.29 q/ha). Intercropping of wheat with gobhi sarson was at par with intercropping of African sarson and lentil. Among the weedy cropping systems, the minimum straw yield was found in intercropping of wheat with gobhi sarson (53.26q/ha) which was at par compared to intercropping of all tried crops except fennel and dil seed.

In the second year (2021-22), significantly higher straw yield was found in wheat weed free cropping system (83.01 q/ha). The wheat weed free was recorded statistically at par with with fennel, dil seed under weed free intercropping system. Among all weedy cropping systems, wheat weed free, dil seed and fennel produced significantly higher straw yield (Table 4.3.9). From the weed free cropping systems, the minimum straw yield was found in intercropping of wheat with gobhi sarson (72.15 q/ha) and it was significantly less as compared with straw yield of wheat intercropped with all tried weed free crops. Among the weedy cropping system, the minimum straw yield was also found in intercropping of wheat with gobhi sarson (54.21 q/ha) which was significantly less than wheat straw yield obtained under all intercrops.

From the pooled data (2020-21 and 2021-22), significantly higher straw yield was found in wheat weed free cropping system (86.13 q/ha) (Table 4.3.9). From the weed free cropping systems, the minimum straw yield was found in intercropping of wheat with gobhi sarson (71.72 q/ha) which was significantly lower than intercropping of fennel and dil seed. The minimum straw yield was also observed in intercropping of wheat with gobhi sarson (53.73 q/ha) which was significantly lower than wheat intercropped with all tried crops. The *Phalaris minor* decreased the wheat straw yield differently in different intercrops. The highest reduction in wheat straw yield was observed in wheat weedy (34.14%) indicating that all tried intercrops helped to smother *Phalaris minor*. The minimum percentage decrease was found in fennel 24.94%. Intercropping of wheat with gobhi sarson, African sarson, fenugreek and dil seed weedy treatment also decreased the straw yield by 25.08%, 25.12%, 25.03%, 26.65% and 26.57% respectively than weed free.

Reduction in the wheat straw yield was more due to mustard crops as these crops are good competitor for inputs. Due to their more height, the straw yield was reduced where as other tried crops were less competitor. Intercropping of fennel and dil seed was found more suitable than all tried intercrops as these was not any significant reduction of wheat straw yield as compared to wheat alone.

Table: 4.3.9: Straw yield (q/ha) of bed planted wheat as influenced by different intercrops

Treatments	Wheat straw yield (q/ha)			
	2020-21	2021-22	Pooled	Percent decrease over weed free
Wheat, weed free	85.21	87.05	86.13	34.14
Wheat, weedy	56.39	57.06	56.72	
Wheat+Gobhi sarson, weed free	71.29	72.15	71.72	25.08
Wheat+Gobhi sarson, weedy	53.26	54.21	53.73	
Wheat+African sarson, weed free	76.77	78.13	77.45	25.12
Wheat+African sarson, weedy	57.70	58.27	57.99	
Wheat+Lentil, weed free	77.89	79.25	78.57	25.03
Wheat+Lentil, weedy	58.11	59.68	58.90	
Wheat+Fenugreek, weed free	80.32	83.93	82.12	26.65
Wheat+Fenugreek, weedy	59.19	61.26	60.23	
Wheat+Fennel, weed free	84.43	85.53	84.98	24.94
Wheat+Fennel, weedy	62.62	64.94	63.78	
Wheat+Dil seed, weed free	83.08	84.44	83.76	26.57
Wheat+Dil seed, weedy	60.84	62.16	61.50	
CD at 5%	7.29	4.04	0.67	

4.3.10 Straw yield of intercrops (q/ha)

The data releted to straw yield of all intercrops was shown in Table 4.3.10. During the first year (2020-21) the significantly more straw yield was found in gobhi sarson weed free cropping system (29.4 q/ha). From the weed free cropping systems, the lower straw yield was found in intercropping of wheat with fenugreek (13.0 q/ha). The intercropping of wheat with fenugreek was found at par with lentil intercropping. Among the weedy cropping system, the minimum straw yield was found in intercropping of wheat with fenugreek (10.82 q/ha) which was found at par with lentil and significantly more than all other intercrops.

In the second year (2021-22), the significantly more straw yield was also found in gobhi sarson weed free cropping system (31.91 q/ha) (Table 4.3.10). From the weed free cropping systems, the minimum straw yield was found in intercropping of wheat with fenugreek (14.7 q/ha) which was found at par with lentil and both these intercrops produced significantly less straw yield as compared to all other intercrops. Among the weedy cropping system, the minimum straw yield was found in intercropping of wheat with fenugreek weedy cropping system (11.2 q/ha) which was significantly less than all other intercrops.

From the pooled data (2020-21 and 2021-22), significantly maximum straw yield was found in gobhi sarson weed free cropping system (30.65 q/ha) (Table 4.3.10). From the weed free cropping systems, the minimum straw yield was found in intercropping of wheat with fenugreek (13.84 q/ha) which was significantly less than all other intercrops. Among the weedy cropping system, the minimum straw yield was found in intercropping of wheat with fenugreek (11.0 q/ha) which was significantly less than the straw weight of all other intercrops. Both the Brassica crops produced more straw yield which was significantly more as compared to lentil and all spice crops. The *Phalaris minor* decreased the straw yield differently in different intercrops. The highest reduction in straw yield was observed in gobhi sarson 22.47%. Intercropping of wheat with African sarson, fenugreek, fennel and dil seed weedy treatment also decreased the straw yield as 12.35%, 16.55%, 20.28%, 14.44% and 13.06% respectively by weedy crop over weed free. These differences were mainly due to their genetic characteristics.

Table: 4.3.10: Straw yield of different intercrops sown in bed planted wheat

Treatments	Straw yield of intercrops (q/ha)			
	2020-21	2021-22	Pooled	Percent decrease over weed free
Wheat+Gobhi sarson, weed free	29.4	31.9	30.7	22.47
Wheat+Gobhi sarson, weedy	23.2	24.4	23.8	
Wheat+African sarson, weed free	24.2	25.9	25.1	12.35
Wheat+African sarson, weedy	21.3	22.7	22.0	
Wheat+Lentil, weed free	13.7	15.3	14.5	16.55
Wheat+Lentil, weedy	11.5	12.7	12.1	
Wheat+Fenugreek, weed free	13.0	14.7	13.8	20.28
Wheat+Fenugreek, weedy	10.8	11.2	11.0	
Wheat+Fennel, weed free	17.4	18.6	18.0	14.44
Wheat+Fennel, weedy	14.8	16.0	15.4	
Wheat+Dil seed, weed free	17.0	18.1	17.6	13.06
Wheat+Dil seed, weedy	14.9	15.8	15.3	
CD at 5%	1.27	1.30	0.44	

4.3.11 Biological yield of wheat (q/ha)

Biological yield is the product of grain yield and straw yield. It depends on many vegetative and reproductive factors. The data relevent to biological yield was shown in the Table 4.3.11. Weed free treatments for different intercrops showed significantly higher biological yield than weedy treatment for their respective crops. Among the different weed free treatments, the higher biological yield was found in the wheat weed free (148.85 q/ha) during 2020-21. In the first year, the intercropping of medicinal crops (fennel and dil seeds) under weed free conditions were found at par with wheat weed free treatment. The biological yield in intercropping of wheat with lentil, fenugreek, gobhi sarson and African sarson under weed free situations were significantly lower than wheat weed free. In the weedy treatments, the lowest biological yield was found in intercropping of wheat with gobhi sarson weedy (89.3 q/ha) which was significantly less than wheat weed free treatment. During the first year, the intercropping of wheat with gobhi sarson weedy was found at par with wheat weedy treatment and wheat with African sarson weedy. The other weedy treatments like intercropping of wheat with lentil, intercropping of wheat with fennel, intercropping of wheat with fenugreek and intercropping of wheat with dil seed showed significantly higher biological yield than intercropping of wheat with gobhi sarson.

During the second year, the higher biological yield was found in the wheat weed free (152.96 q/ha). The intercropping of medicinal crops under weed free conditions (fennel and dil seeds) were found at par with wheat weed free treatment (Table 4.3.11). The biological yield under intercropping of wheat with lentil, fenugreek, gobhi sarson and African sarson under weed free situations were significantly lower than wheat weed free. In the weedy treatments, the lowest biological yield was found in intercropping of wheat with gobhi sarson weedy (89.16 q/ha) which was significantly less than wheat weed free treatment. In the second year, the intercropping of wheat with gobhi sarson weedy was found at par with wheat weedy treatment and wheat with African sarson weedy. The other weedy treatments like intercropping of wheat with lentil, intercropping of wheat with fennel, intercropping of wheat with fenugreek and intercropping of wheat with dil seed gave significantly higher biological yield than intercropping of wheat with gobhi sarson.

It was concluded from the pooled data (2020-21 and 2021-22) that, the significantly higher biological yield was found in the wheat weed free (150 q/ha) (Table 4.3.11). In the weedy treatments, the significantly lowest biological yield was found in intercropping of wheat with gobhi sarson weedy (89.23 q/ha) and this reduction was due to reduction in biological yield of wheat as it was more smother by gobhi sarson. The intercropping of wheat with lentil weedy was found at par with the intercropping of wheat with fenugreek weedy. The *Phalaris minor* decreased the wheat biological yield differently in different intercrops. The more reduction in biological yield was observed in wheat weedy (39.42%), followed by gobhi sarson, 29.86%. The minimum percentage decrease was found in lentil crop (23.59%). Intercropping of wheat with African sarson, fenugreek, fennel and dil seed weedy treatment also decreased the biological yield by 28.34%, 26.16%, 25.20%, 25.38% respectively over weed free treatments. Biological yield of each intercrop was significantly less in weedy conditions over their respective weed free treatments.

Table: 4.3.11: Biological yield of wheat (q/ha) in bed planted wheat as influenced by different intercrops (q/ha)

Treatments	Biological yield of wheat (q/ha)			
	2020-21	**2021-22**	**Pooled**	**Percent decrease over weed free**
Wheat, weed free	148.85	152.96	150.90	39.42
Wheat, Weedy	92.70	93.11	92.91	
Wheat+Gobhi sarson, weed free	125.53	128.92	127.22	29.86
Wheat+Gobhi sarson, Weedy	89.30	89.16	89.23	
Wheat+African sarson, weed free	132.60	135.35	133.97	28.34
Wheat+African sarson, Weedy	95.80	96.20	96.00	
Wheat+Lentil, weed free	134.56	137.61	136.08	23.59
Wheat+Lentil, Weedy	102.76	105.17	103.97	
Wheat+Fenugreek, weed free	138.23	143.18	140.70	26.16
Wheat+Fenugreek, Weedy	102.58	105.18	103.88	
Wheat+Fennel, weed free	146.51	149.48	148.00	25.20
Wheat+Fennel, Weedy	108.95	112.44	110.69	
Wheat+Dil seed, weed free	142.54	145.66	144.10	25.38
Wheat+Dil seed, Weedy	105.70	109.34	107.52	
CD at 5%	8.21	7.33	1.24	

4.3.12 Biological yield of intercrop (q/ha)

The data releated to the effect of different treatments on biological yield was given in the Table 4.3.12. During the first year (2020-21), the highest biological yield was found in gobhi sarson weed free (36.92 q/ha) followed by African sarson weed free (30.01 q/ha) and both these treatments produced significantly higher biological yield than all other intercrops. All weed free intercrops had significantly higher biological yield than their respective weedy treatments. The lowest biological yield was found in fenugreek weedy intercrop which was significantly lower than all other intercrops except lentil weedy. The fenugreek weed free was found at par with dil seed weedy, fennel weedy and lentil weed free intercrops. The fennel weed free was at par with dil seed weed free with respect to biological yield.

During the second year (2021-22), the maximum biological was found in gobhi sarson weed free (39.69 q/ha) which was significantly higher than all other intercrops followed by African sarson weed free (30.01 q/ha) (Table 4.3.12). All weed free intercrops recorded significantly higher biological yield than their respective weedy treatments. The minimum biological yield was found in fenugreek weedy intercrop which was significantly lower than all other intercrops. The fenugreek weed free was found at par with dil seed weedy and fennel weedy intercrops. The fennel weed free was at par with dil seed weed free.

It can be concluded from the pool data (2020-21 and 2021-22), the maximum biological was found in gobhi sarson weed free (38.30 q/ha) which was significantly higher than all other intercrops followed by African sarson weed free (30.94 q/ha) (Table 4.3.12). Significantly higher biological yield was recorded in all weed free intercrops as compared to weedy whereas the lower biological yield was recorded in fenugreek weedy intercrop and it was significantly lower than all other intercrops. The dil seed weedy was found at par with fennel weedy and lentil weed free intercrops. The biological yield of fennel weed free was at par with dil seed weed free. The *Phalaris minor* decreased the intercrop biological yield differently in different intercrops. The highest reduction in intercrop biological yield was observed in gobhi sarson (26.81%). The minimum percentage decrease was found in African sarson (15.41). Intercropping of wheat with lentil, fenugreek, fennel and dil seed weedy treatment also decreased the biological yield by 18.20%, 21.85%, 17.42%, 16.92% respectively by weedy crop over weed free.

Table: 4.3.12: Biological yield (q/ha) of different intercrops sown in bed planted wheat

Treatments	Biological yield of intercrops (q/ha)			
	2020-21	**2021-22**	**Pooled**	**Percent decrease over weed free**
Wheat+Gobhi sarson, weed free	36.92	39.69	38.30	26.81
Wheat+Gobhi sarson, Weedy	27.34	28.73	28.03	
Wheat+African sarson, weed free	30.01	31.88	30.94	15.41
Wheat+African sarson, Weedy	25.78	26.56	26.17	
Wheat+Lentil, weed free	16.95	18.65	17.80	18.20
Wheat+Lentil, Weedy	13.95	15.17	14.56	
Wheat+Fenugreek, weed free	15.38	17.20	16.29	21.85
Wheat+Fenugreek, Weedy	12.52	12.94	12.73	
Wheat+Fennel, weed free	20.53	21.94	21.23	17.42
Wheat+Fennel, Weedy	16.93	18.13	17.53	
Wheat+Dil seed, weed free	20.35	21.49	20.92	16.92
Wheat+Dil seed, Weedy	16.89	17.87	17.38	
CD at 5%	1.60	1.36	0.52	

4.3.13 Harvest index of wheat (%)

Harvest index can be calculated as

$$\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Harvest index is an essential parameter which shows effectiveness of DM accumulation to the crops economic part. The data relevent to the effect of different treatments on harvesting index was given in the Table 4.3.13. During the first year (2020-21), the highest harvest index of wheat was found in wheat weed free (42.75). The lowest harvest index of wheat was found in wheat weedy (39.17). In the oil seed intercropping systems, the weed free treatments had better harvest index of wheat as compare to weed free but in medicinal crops, the harvest index of weedy treatments was more as compared to weed free except dil seed.

In the second year (2021-22), the highest harvest index of wheat was found in wheat weed free (43.16) (Table 4.3.13). The lowest harvest index of wheat was found in wheat weedy (38.72). In the oil seed intercropping, the weed free treatments had better harvest index of wheat as compare to weed free but in medicinal crops, the harvest index of weedy treatments was more as compared to weed free except fennel.

From the pooled data (2020-21 and 2021-22), the highest harvest index of wheat was found in wheat weed free (42.96) (Table 4.3.13). The lowest harvest index of wheat was found in wheat weedy (38.94). In the oil seed intercropping, the weed free treatments had better harvest index of wheat as compare to weed free but in medicinal crops, the harvest index of weedy treatments was more as compared to weed free except dil seed.

Table 4.3.13: Harvest index (percent) of wheat in bed planted wheat as influenced by different intercrops

Treatments	Harvest index of wheat (percent)		
	2020-21	2021-22	Pooled
Wheat, weed free	42.75	43.16	42.96
Wheat, weedy	39.17	38.72	38.94
Wheat+Gobhi sarson, weed free	40.36	40.87	42.04
Wheat+Gobhi sarson, weedy	40.21	39.20	39.78
Wheat+African sarson, weed free	42.10	42.28	42.19
Wheat+African sarson, weedy	39.77	39.42	39.60
Wheat+Lentil, weed free	42.11	42.41	42.26
Wheat+Lentil, weedy	40.45	40.25	40.35
Wheat+Fenugreek, weed free	41.89	41.38	41.64
Wheat+Fenugreek, weedy	42.30	41.75	42.02
Wheat+Fennel, weed free	42.38	42.78	42.58
Wheat+Fennel, Weedy	42.52	42.24	42.38
Wheat+Dil seed, weed free	41.71	42.03	41.87
Wheat+Dil seed, Weedy	42.44	43.09	42.77

4.3.14 Harvest index of intercrops (percent)

The data relevant to harvest index of intercrops was given in the Table 4.3.14. During the first year (2020-21), the maximum harvest index was found in gobhi sarson weed free (20.26) followed by African sarson weed free (19.27). The minimum harvest index was found in dil seed weedy (11.99). All weed free treatments had better harvest index as compared with weedy treatments.

During the second year (2020-21), the maximum harvest index of intercrops was found in gobhi sarson weed free (19.62) followed by African sarson weed free (18.83). The minimum harvest index of wheat was found in dil seed weedy (11.86). All weed free treatments had better harvest index as compared with weedy treatments.

The data analysed from pooled data (2020-21 and 2021-22), the highest harvest index of different intercrops was found in gobhi sarson weed free (19.94) followed by African sarson weed free (19.05). The lowest harvest index was found in dil seed weedy (11.93). All weed free treatments had better harvest index as compared with weedy treatments.

Table: 4.3.14: Harvest index (percent) of different intercrops sown in bed planted wheat

Treatments	Harvest Index of intercrops (%)		
	2020-21	2021-22	Pooled
Wheat+Gobhi sarson, weed free	20.26	19.62	19.94
Wheat+Gobhi sarson, Weedy	15.15	15.05	15.10
Wheat+African sarson, weed free	19.27	18.83	19.05
Wheat+African sarson, Weedy	17.33	14.39	15.86
Wheat+Lentil, weed free	19.39	18.25	18.82
Wheat+Lentil, Weedy	17.79	16.00	16.90
Wheat+Fenugreek, weed free	15.71	14.60	15.15
Wheat+Fenugreek, Weedy	13.58	13.43	13.51
Wheat+Fennel, weed free	15.17	15.19	15.18
Wheat+Fennel, Weedy	12.56	12.00	12.28
Wheat+Dil seed, weed free	16.40	15.73	16.07
Wheat+Dil seed, Weedy	11.99	11.86	11.93

4.4 Net profit (Rs./ha)

The net profit of wheat and alternate intercrops was determined by using return over variable cost and WEY (wheat equivalent yield). The prevailing costs of input and market rate of the produce determined the gross income and net profit was calculated by substracting return over variable cost from gross income. The data pertaining to the net profit which was calculted by using WEY has been shown in Table 4.4. It can be concluded from the pooled data analysis (2020-21 and 2021-22) that the maximum gross income was found in dil seed weed free (Rs. 164350/ha) followed by fennel weed free (Rs. 159871/ha) (Table 4.4) which was higher than wheat and all other intercrops. The minimum gross income was found in wheat weedy (Rs. 71458/ha). The highest cultivation cost was Rs. 56841/ha recorded in fennel weed free and was highest from wheat and all other intercrops. It was followed by dil seed weed free (Rs.55891/ha). The minimum cost for cultivating the crop was recorded in wheat weedy (Rs.33541/ha). Maximum net profit was found in dil seed weed free (Rs. 108459/ha) followed by fennel weed free (Rs.103030/ha) which was higher than wheat and all other intercrops. From the weed free treatments, the net profit of lentil and fenugreek was lower as compared with wheat weed free. The gobhi sarson and African sarson gave higher net profit than wheat, lentil and fenugreek. All weed free intercrops had higher net profit than weedy. The minimum net profit was found in wheat weedy (Rs. 37917/ha) which was lower than all other intercrops. From the weedy treatments, the dil seed and fennel gave higher net profit than other weedy treatments. The higher B:C ratio was found in dil seed (1.94) followed by fennel (1.81). The lower B:C ratio was found in intercropping of wheat with fenugreek weedy (0.91).

It can be concluded from the two years data that the maximum net profit was given by medicinal crops (dil seed and fennel). The market price of these two crops was higher due to this, these crops gave maximum wheat equivalent yield which increased net returns. It can also be found that the mustard crops, gave higher returns than the wheat crop both under weedy and weed free conditions. The crops like fenugreek and lentil gave less net returns as compared with wheat weed free crop due to their low yields.

Table: 4.4: Gross income, Expenditure and Net profit (Rs./ha) of different intercrops sown in bed planted wheat

Treatments	Gross income (Rs./ha	Expenditure (Rs./ha)	Net profit (Rs./ha)	B:C
Wheat, weed free	127931	46201	81730	1.77
Wheat, Weedy	71458	33541	37917	1.13
Wheat+Gobhi sarson, weed free	145194	55466	89728	1.62
Wheat+Gobhi sarson, weedy	89840	42806	47034	1.10
Wheat+African sarson, weed free	139048	55241	83806	1.52
Wheat+African sarson, weedy	94375	42581	51793	1.22
Wheat+Lentil, weed free	130608	63641	66967	1.05
Wheat+Lentil, Weedy	101448	50981	50467	0.99
Wheat+Fenugreek, weed free	131898	63641	68257	1.07
Wheat+Fenugreek, weedy	97536	50981	46555	0.91
Wheat+Fennel, weed free	159871	56841	103030	1.81
Wheat+Fennel, Weedy	113520	44181	70621	1.60
Wheat+Dilseed, weed free	1643450	55891	108459	1.94
Wheat+Dilseed, Weedy	114581	43231	71709	1.66

Note- Net profit was calculated on the basis of wheat equivalent yield.

Chapter 5 SUMMARY AND CONCLUSION

This research work entitled **"Productivity, profitability and soil seed bank status of *Phalaris minor* Retz. as influenced by different rice based cropping systems as well as intercropping in bed planted wheat (*Triticum aestivum* L.)"** had been conducted in the experimental field of Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara during the *Rabi* season of 2020-2021 and the field experiment was repeated in the next Rabi season of 2021-2022. Area of experiment had texture of soil in sandy loam which was low in available N_2O and P_2O_5 with medium availability and K_2O. Result has been summarized as below:

Experiment 1: Role of different *Rabi* crops for controlling *Phalaris minor* in comparison to wheat (*Triticum aestivum* L.)

5.1 Count of *Phalaris minor* (per sq.m)

Phalaris minor infestation in the cropped field directly influences the total crop yield. Counts of *Phalaris minor* were observed periodically at 30, 60, 90 DAS and at harvest. The higher count of *Phalaris minor* was found in wheat weedy followed by African sarson (T), African sarson (s) and all these crops recorded significantly more count of *Phalaris minor* except barley than all alternate to wheat crops. The minimum count of *Phalaris minor* was found in wheat weed free treatment. The least count of *Phalaris minor* was found in berseem, oats and potato, which was significantly lower than wheat weedy treatment. Reduction of *P minor* population was mainly due to digging of potato or due to repeated cuttings of fodder crops like berseem & oats.

5.2 Dry matter of *Phalaris minor* (q/ha)

Dry matter of weeds is most reliable parameter than weed count for estimating crop yield losses. Dry matter of *Phalaris minor* were noted periodically at 30, 60, 90 DAS and at harvest. Wheat weedy gave maximum dry matter of *Phalaris minor* followed by barley which was significantly higher than other cropping systems whereas wheat weed free found minimum dry matter of *Phalaris minor*, berseem, oats and potato which was significantly less than all other alternate cropping system. Vegetatively growing Gobhi sarson and raya recorded less dry matter of *Phalaris minor* plants than African sarson.

5.3 Plant height (cm)

Plant height is furthermost parameter of plant development. The periodic plant height was observed at 30, 60, 90 days after sowing (DAS) and at harvest. In the initial stages, the maximum height was found in raya followed by oats and was significantly higher as compared with wheat weedy. These crop rotations were found at par with wheat weed free, barley and gobhi sarson (T) and berseem. The minimum height was found in lentil which was significantly lower than all Brassica crops and wheat (weedy and weed free). It was found that plant height of wheat was at par with potato-carrot and potato-radish crop rotations. At harvest, the maximum height was found in gobhi sarson (T) followed by raya and was significantly higher on comparison with all treatments. Berseem had significantly lower plant height than all treatments. Difference in their height was due to their genetically potential.

5.4 Dry matter of crops (q/ha)

In the initial stages, gobhi sarson transplanted had maximum dry matter of crop during both years (6.7 q/ha and 7.8 q/ha) and wheat weed free along with barley and gobhi sarson (s) was at par with it. They had significantly higher dry matter as compare with wheat weedy. Potato-carrot was found minimum dry matter during both years (1.1 q/ha and 1.1 q/ha) and was at par with potato-radish, fennel, dill seed, lentil and berseem crop rotations than wheat and barley. During harvesting time, the maximum DM was found in barley during both years (44.2 q/ha and 45.7 q/ha) followed by wheat weed free. From all the treatments, significantly lower dry matter was found in berseem

5.5 Spike length/pod length (cm)

The spike length/ pod length influences the final crop yield, as number of grains usually increases with the increased spike length. Among all crops, barley had maximum spike length followed by wheat weed free treatment. The more pod length was found in gobhi sarson transplanted followed by gobhi sarson seeded which was significantly higher as compare to other mustard crops.

5.6 Number of grains per spike/pod

No. of grains per spike/pod enhanced the yield. Barley had maximum no. of grains per spike higher than other crops followed by wheat weed free. The least number of grains was found in lentil crop rotation which was found at par with radish.

5.7 Crop yield (q/ha))

The highest yield was found in fodder berseem crop during both years (406.75 q/ha and 457.78 q/ha) which was followed by oats fodder and seeds and both these crops gave significantly higher yield than other crops. The minimum seed yield was found in African sarson seeded crop (7 q/ha) which was significantly lower as compare with berseem, oats, barley, wheat weed free and potato.

5.8 Wheat equivalent yield (q/ha)

Wheat equivalent yield was calculated on the basis of individual yield of different crops and determine impact of different crops to generate comparable yield data. The maximum wheat equivalent yield was found in potato-radish (155.78 q/ha 251.24 q/ha) and potato-carrot crop rotation (164.84 qha and 249.99 q/ha) as compared with wheat weed free. The minimum wheat equivalent yield was found in African sarson seeded (16.70 q/ha) which was significantly lower as compare with potato-radish, potato-carrot barley, lentil and fennel and wheat weed free treatments.

5.9 Soil seed bank

The soil seed bank of *P. minor* was determined at experiment termination i.e., end of April 2022 from soil collected 0-15 cm top depth from one square feet. Seeds of *Phalaris minor* were separated by washing the soil with water in a sieve. The maximum seed number was found in wheat weedy (585.5) which was significantly higher as compare to all other alternative to wheat cropping systems. The minimum number of seeds recorded in wheat weed free (0). Berseem, potato-radish, potato-carrot and oats fodder and seed had minimum seeds as well. Continuous sowing of berseem, oats, potato-radish and potato carrot for two years after rice have completely eliminated *Phalaris minor* seed production

5.10 Net profit

The net profit of wheat and alternate to wheat *Rabi* crops determined with the help of wheat equivalent yield by using the prevailing costs of input and market rate of the produce. From the pooled data analysis (2020-21 and 2021-22) that the maximum gross income was found in potato-carrot (Rs.409642 per ha) followed potato-radish crop rotation (Rs.401931 per ha). The minimum gross income was found in African sarson transplanted (Rs.36641 per ha). The maximum net profit was found in potato-carrot crop rotation (Rs.313650 per ha) followed by potato-radish crop rotation (Rs.307468.3). Oats as fodder and seed had net profit of Rs.229317 per ha & berseem of Rs.132882 per ha which was higher as compared with traditional practice of growing wheat. The minimum net profit was found in African sarson transplanted (Rs.8778 per ha).

Experiment 2: Smothering potential of different intercrops on *Phalaris minor* in bed planted technology of wheat sowing

5.11 Count of *Phalaris minor* (per sq.m)

The count of *P. minor* was observed at 30, 60, 90 DAS and at harvest. Among weedy cropping systems, the maximum count of *Phalaris minor* was found in wheat weedy cropping system (7.75 and 7.84) during harvesting which was significantly more than weedy check of all tried crops. Among the weedy systems, the significantly less count of *Phalaris minor* was found in intercropping of wheat with gobhi sarson cropping system than all other weedy cropping systems. Among all intercrops, the smothering potential of fennel and dill seed was comparatively more than other tried crops. Also, gobhi sarson showed more smothering potential due to its wider leaves than African sarson when observations were recorded at all periodic intervals.

5.12 Dry matter of *Phalaris minor* (q/ha)

Dry matter of *P. minor* was noted periodically at 30, 60, 90 DAS and at harvest. Significantly higher dry matter was found in wheat weedy intercropping systems during harvesting

(5.67 q/ha and 5.86 q/ha). The lentil weedy gave significantly higher dry matter African sarson weedy intercropped with wheat. The gobhi sarson had minimum dry matter of *Phalaris minor* and was lower than all weedy intercropping systems. Among Brassica crops, gobhi sarson showed more smothering effect on *Phalaris minor* than African sarson for reducing dry matter of *Phalaris minor* which may be due to broader leaves of gobhi sarson than African sarson. From spices, fenel and dil seed smothered *Phalaris minor* effectively than fenugreek.

5.13 Plant height of wheat (cm)

Plant height of wheat observed at 30, 60, 90 DAS and at harvest. Wheat weed free had maximum height followed by intercropping of wheat with fennel and dill seed weed free treatment. The lowest height from all weedy treatments was found in intercropping of wheat with gobhi sarson. The fennel and dill seed showed less competition with main crop (wheat) whereas gobhi sarson and African sarson due to their more height than wheat resulted in reduction of wheat plant height.

5.14 Intercrop height (cm)

The height of intercrops was observed at 30, 60, 90 DAS and at harvest. All weed free treatment of different intercrops significantly increased plant height than their respective weedy treatments. The height of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment. Plant height of intercrops viz. African sarson, lentil, fenugreek, fennel and dill seed under weedy conditions had significantly lower height. From the medicinal crops, the plant height in fennel crop and dil seed was found at par under weedy and weed free conditions.

5.15 Dry matter of wheat (q/ha)

DM of wheat determined periodically at 30, 60, 90 DAS and at harvest. The maximum wheat dry matter was found in wheat weed free during harvesting in both years (63.65 q/ha and 65.92 q/ha). The intercropping of wheat with fennel gave higher dry matter of wheat than other intercropping systems. The intercropping of wheat with gobhi sarson gave minimum wheat dry matter during harvesting (37.75 q/ha and 38.55 q/ha) and was found at par with African sarson. Intercropping of wheat with gobhi sarson significantly recorded minimum dry matter of wheat crop.

5.16 Total number of tillers (per m row length)

The yield of each crop was enhanced by increasing the number of tillers as it the major yield attribute. The no. of tillers were recorded at 30, 60, 90 DAS and at harvesting time. Maximum numbers of tillers were found in the wheat weed freein both years at harvesting time (97.3 and 98.5). The wheat weed free cropping system was statistically at par with intercropping of wheat with fennel and with dill seed weed free cropping systems. Under weed free, minimum count of tillers were observed in intercropping of wheat with gobhi sarson during harvesting which were found at par with intercropping of wheat with African sarson and lentil. From the weedy cropping system, the minimum count of tillers were found in intercropping of wheat with gobhi sarson (66.3 and 67.5) which were found at par with intercropping of wheat with African sarson, lentil, fenugreek and wheat. All weed free cropping systems of all crops had significantly more no. of tillers per meter row length than their respective weedy cropping systems.

5.17 Effective tillers (per m row length)

Effective tillers are directly related to wheat yield. The maximum effective tillers were recorded in the wheat weed free in both years (84.8 and 85.3). The intercropping of wheat with fennel, dil seed and fenugreek and all these cropping systems gave significantly higher effective tillers than all weedy cropping systems. From the weed free cropping systems, the minimum effective tillers were observed in intercropping of wheat with gobhi sarson (59.3 and 62.3) and these were found at par with African sarson, lentil and fenugreek.

5.18 Pod length (cm)

Increase in the length of pod would increases the yield. The maximum pod length was found in fenugreek weed free (7.09cm and 7.43cm) followed by fenugreek weedy. All weed free treatment of different intercrops significantly increased pod length than their respective weedy treatment. The pod length of gobhi sarson weed free was significantly higher than gobhi sarson weedy treatment.

5.19 Numbers of grains per spike

The maximum number of grains per spike were found in the wheat weed free during both years 44.5 and 49.8 respectively. The intercropping of wheat with fennel weed free was observed at par with wheat weed free. From the weed free cropping systems, the lower numbers of grains per spike were found in gobhi sarson (30.8 and 32.5) which was found at par with intercropping of wheat with African sarson and wheat weedy.

5.20 Wheat yield (q/ha)

For calculating the net profit, grain yield of crop plays vital role in it. Weed free treatments for different intercrops showed significantly higher wheat grain yield than weedy treatment for their respective crops. Highest grain yield was found in wheat weed free in both years 63.64 q/ha and 65.91 q/ha respectively. The intercropping of medicinal crops under weed free conditions (fennel and dill seeds) were found at par with wheat weed free. Wheat along with lentil, fenugreek, gobhi sarson and African sarson under weed free situations reduced wheat yield significantly than wheat weed free. In the weedy treatments, the lowest grain yield was found in intercropping of wheat with gobhi sarson weedy (36.0 q/ha and 34.95 q/ha) which was significantly less than wheat weed free treatment.

5.21 Wheat equivalent yield (q/ha)

The wheat equivalent yield of different intercrops was determined on the basis of MSP of a particular crop. The highest wheat equivalent yield was found in intercropping of wheat with dill seed weed free in both yeas 81.44 q/ha and 84.99 q/ha respectively followed by intercropping of wheat with fennel crop weed free in two year experiment (79.42 q/ha and 82.47 q/ha) and both these intercropping systems significantly increased wheat equivalent yield than wheat weedy alone (36.31 q/ha and 36.05 q/ha) in both years which was lower than the standard practice of the farmers. From all other weedy intercropping systems, significantly lowest WEY was found in wheat weedy treatment. From different intercropping treatments, the lowest wheat equivalent yield was found in intercropping of wheat with gobhi sarson weedy treatment.

5.22 Net profit

The net profit of wheat and alternate intercrops was determinate on the basis of WEY by calculating the prevailing input cost and market rate of the produce. From the pooled data analysis (2020-21 and 2021-22) that the maximum gross income was found in dil seed weed free (Rs. 164350/ha) followed by fennel weed free (Rs. 159871/ha) which was higher than wheat and all other intercrops. The minimum gross income was found in wheat weedy (Rs. 71458/ha). The maximum net profit was found in dil seed weed free (Rs. 108459/ha) followed by fennel weed free (Rs. 103030/ha) which was higher than wheat and all other intercrops. The minimum net profit was found in wheat weedy (Rs. 37917/ha) which was lower than all other intercrops. From the weedy treatments, the dil seed and fennel gave higher net profit than other weedy treatments.

Salient findings:

- In the first experiment, potato followed by radish (155.78 q/ha and 251.24 q/ha) and potato followed by carrot (164.84 q/ha and 249.99 q/ha) crop rotation gave the maximum yield of wheat equivalent during both years followed by oats for fodder & seed.
- In the second experiment, highest wheat equivalent yield was found in intercropping of wheat along with medicinal crops dill seed (81.44 q/ha and 84.99q/ha) and fennel (79.42 q/ha and 82.47 q/ha) as compared to other crops. Among Brassica crops, the maximum grain yield of wheat was reduced by gobhi sarson more than African sarson.
- In the first experiment, *Phalaris minor* count and dry matter was significantly less in berseem, potato-radish, potato-carrot and oats fodder and oats seed crop rotations.
- In the second experiment, Fennel and dill seed significantly decrease the count of *Phalaris minor* at all periodic intervals. During harvesting of both years fennel had 34.40 less count of *Phalaris minor* on comparison with wheat weedy.
- Potato-radish, potato-carrot, berseem and oats (fodder and seed) completely eliminated *P.mino*r after their rotation of two years because no *P.minor* was found after termination of experiment where as the maximum number of seeds were found in wheat weedy (585.5).

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APPENDICES

Appendix

Cost of cultivation of wheat

Sr.No	Particulates	Price (Rs.)	Inputs	Total cost (Rs/ha)
1.	Seed	45 per kg	100kg/ha	3750
2.	Fertilizers			
i)	Urea	280 per bag	275kg/ha	1711
ii)	DAP	1300 per bag	137.5kg/ha	3575
3.	Labour charges			
i)	Labour (plot preparation, sowing + harvesting labour)	422/day/per person		16880(12660+4220)
4.	Field preparation (tractor rent)	1500/Acre		3750
5.	Electricity charges			2000
6.	Insecticide+pesticide			1875
	Total (without weed control)			33541
7.	Hand weeding			12660
	Total (weed control done with hand weeding)			46201

LIST OF CONFERENCES & WORKSHOPS

- Poster Presentation in International Conference on "*Global Efforts on Agricultural, Forestry, Environment and Food Security*" on 17 to 19 September 2022organized by Tribhuvan University, Pokhara, Nepal.

- Oral Presentation in International Conference on "*International Conference onAdvances in Agriculture Technology and Allied Sciences"* on 4 to 5 June 2022 organized at Centurion University of Technology and Management, Paralakhemundi, Gajapati, Odisha, India.

PAPER FOR Ph.D

TITLE OF PAPER WITH AUTHOR NAMES	NAME OF JOURNAL / CONFERENCE	PUBLISHED DATE	ISSN NO/ VOLNO, ISSUE NO
Influence of various *Rab*i season intercrops with wheat on yield attributes **Author's names** Tarun Sharma, U.S. Walia, Supreet Saajan	European Chemical Bulletin	28- July-2023	ISSN: 2063-5346/ vol. No. 12 (Special Issue 10), 1076-1082