“**Performance of herbicides to control *Phalaris minor* as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum*)**”

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

in

AGRONOMY

By

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Transforming Education Transforming India

LOVELY PROFESSIONAL UNIVERSITY
PUNJAB
2021

DECLARATION

I do here by declare that this thesis entitled **"Performance of herbicides to control *Phalaris minor* as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum*)"** is a bonafied record of the research work carried out by me and no part of the thesis has been submitted earlier to any University or Institute for the award of any degree or diploma.

Date: 11-feb-2021

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(Supreet Saajan)

Certificate-I

This is to certify that this thesis entitled **"(Performance of herbicides to control *Phalaris minor* as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum*)"** being submitted by Supreet Saajan for the award of Degree of Doctor of Philosophy (Agronomy) to the Lovely Professional University is a record of bonafied research work carried out by him under our supervision and guidance. The thesis has reached the standard fulfilling the requirements of the regulation relating to the degree.

(Dr.Premasis Sukul)	**(Dr.Ujagar Singh Walia)**
(Major Advisor)	**(Co- Advisor)**

CERTIFICATE- II

This is to certify that the thesis entitled **"Performance of herbicides to control *Phalaris minor* as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum*)"** submitted by Supreet Saajan to the Lovely Professional University, Phagwara in partial fulfilment of the requirements for the degree of Doctor of Philosophy (Agronomy) has been approved by the Advisory Committee after a nodal examination of the student in collaboration with an External Examiner.

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List of symbols and abbreviations

%	: Percent
@	: at the rate
i.e.	: That is
m	: meter
cm	: centimeter
kg	: kilogram
gm	: gram
N	: nitrogen
RDN	: Recommended dose of nitrogen
FYM	: farm yard manure
ha	: hectare
P_2O_5	: Phosphorus
K_2O	: Potassium
Kg N/ha	: kilogram Nitrogen per Hectare
^{o} C	: Degree
pH	: Potentials of Hydrogen ions
DAS	: Days after sowing
EC	: Electrical Conductivity
RBD	: Random Block Design
T	: Treatment
et al.,	:And others
dSm^{-1}	: Decisiemen per meter

fig. :Figure

no. :Number

RDF : Recommended dose of fertilizer

Tab :Table

P : Phosphorus

DM : Dry Matter

N_3 : Nitrite

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Place: LPU, Phagwara

Dated: April, 2017 **(Supreet Saajan)**

Abstract

A field experiment was conducted at the farm of Lovely Professional University, Phagwara during Rabi season of 2018-19 and 2019-20 to determine the effects of sowing dates and weed management practices on the growth of *Phalaris minor* in wheat (*Triticum aestivum* L.) under Punjab agro-climatic conditions. The investigations revealed that early sowing (first week of November) exerted a significant effect to decrease the population and dry matter of *Phalaris minor*. Among different weed management treatments, application of (sulfosulfuron + metsulfuron methyl 30 g/ha) recorded the significantly lowest population and dry matter accumulation of weeds. The crop sown during the first week of November 2018- 19 and 2019-20 recorded 75.50 and 71.55 % higher weed control efficiency. Results showed that the herbicides metribuzine + clodinafop propanyl, and metribuzine were found to be non-resistant to different biotypes. The bidirectional sowing method significantly increased the grain yield of wheat and decreased the density of weeds. The B1 and B2 biotypes were more resistant to herbicides than other biotypes.

Keyword: *Phalaris minor,* yield attributes, dry matter, herbicides

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal crop and grown extensively throughout the world. It is the main staple food in the world. The wheat crop covers nearly 14 percent of the global area which produces about 99.70 million tonnes of grains with average productivity of 3371 kg/ha, corresponding to 13.64 percent of world production (Ramadas *et al*., 2019). Wheat crop contributes a significant share in consumption and production. It contributes 36 percent of total cereal grains from India. It ensures food security along with nutrition security. In India, wheat grains are mostly procured by the government and are distributed through the public distribution system to the majority of the population to ensure food security. Wheat possesses a higher protein content than maize and rice, which makes it a good source of proteins in the human diet. Wheat is consumed in various processed forms and different preparations from ancient times. In Northern India, it is considered as the staple food and the population in this region is dependent on chapatti for their daily nutritional intake. The second-largest producer of wheat is India followed by China, accounting for 12% of the global wheat production.

It is a widely adapted crop and grown under different environmental conditions. This wide range of adaptation is possible due to the genome (complex in nature), which provides great plasticity to the crop (Gupta *et al*., 2010). In India, wheat generally is cultivated from November to April during the *rabi* season (sowing during November and harvesting in April). The area under cultivation of wheat has shown an increasing trend in India with a 5 percent net gain in the area at the national level. However, a major expansion in the wheat area is observed in the states such as Jharkhand (51 percent), Madhya Pradesh (27 percent), and Rajasthan (13 percent). Punjab and Haryana provide the highest productivity at a national level (Ramadas *et al*., 2019).

The wheat cultivating area in India has shown a rise from 29.04 million hectares to 30.54 million hectares with a net increase of 1.5 million hectares (Ramadas *et al*., 2019). Uttar Pradesh is the largest wheat cultivating state in terms of area with 9.75 million hectares (32%), followed by Madhya Pradesh with 18.75%, Punjab with 11.48%, Rajasthan with 9.74%, Haryana with 8.36% and Bihar with 6.82% (Ramadas *et al*., 2019). Recently, some other states are also showing major interests in wheat cultivation with a quick rise in their wheat cultivation areas such as Jharkhand (51%) and Rajasthan (13%). The wheat production in India has shown a significant rise from 2013-2018 with production ranging from 87.39 million tonnes to 94.57 million tonnes with a magnitude of 7.18 million tonnes (Ramadas *et al*., 2019). Around 90% of the wheat produced in India is from traditional wheat growing regions such as Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Bihar, and Rajasthan. However, a reduction of 1.4 million tonnes in wheat production was observed from 2013-2018 in Uttar Pradesh which is a matter of concern.

Despite the large production of wheat in India, a heavy portion of the wheat production is lost during the cultivation process. One of the most important reasons for this is the weed infestation. Weed is an unwanted plant that establishes itself in the main crops and competes with them for sunlight, spacing, water, and nutrients. Weeds are very harmful to the wheat crop and cause heavy damage, either directly or indirectly. When competing with the main crop, the weeds degrade the soil nutrient availability and reduce the soil moisture and thus directly reduce the crop quality and yield. As for the indirect damage, the weeds act as alternate hosts for the pests and diseases, ultimately leading to reduced crop yield and in turn low economic income. Weed management involves cost and thereby, leading to less net farm returns. The management can include hiring labours, purchasing herbicides, and other implements for weeding operations. It is estimated that weeds in wheat cause yield loss of about 40-50% depending on their intensity. Several weeds with diversified types and nature are available in the wheat field, which range from narrow-leaf weeds to broad-leaf weeds. The narrow-leaf weeds prevalent in the wheat field are *Phalaris minor* (Gullidanda), *Avena fatua* (Wild oat) and *Asphodelius tenuifolius* (Piazi). The broad-leaved weeds are *Chenopodium album* (Batua), *Fumaria parviflora* (Gazari), *Melilotus alva* (Sengi), *Argemone mexicana* (Satyanashi), *Anagallis arvensis* (Krishneel), *Cirsiumarvensis* (Katili), and *Lathyrus aphaca* (Chatarimatari). Apart from these weeds, a perennial weed *Cyanadon dactylon* (doob grass) is also found in the wheat field throughout the season. In India, with the introduction of dwarf wheat varieties, the two major weeds of wheat were also introduced i.e., *Phalaris minor* (Gullidanda) and *Avena fatua* (Wild oat). They act as a nuisance to the farmers, especially *Phalaris minor* and sometimes its density in the crop field is so high (2000 to 3000/meter square) that the farmers harvest the main crop as the fodder, leading to a huge loss. This weed is majorly prevalent in the Northern wheat growing parts of India like Punjab and Haryana.

Weeds are plants, which are out of their appropriate place. They are considered the most unfortunate, forceful and problematic component of the world's vegetation. Nutrients, light and space are the factors for which they compete with the main crop. If the population of weed remains uncontrolled, they exert harmful effects on the quality and quantity of the crop yield (Arnold *et al*., 1988, Halford *et al*., 2001). Weeds act as the major source of diseases in crops and also support the pest attack in a crop. Several insect/pests use them as alternate or collateral hosts for nourishment and asylum during the off-time period. The major factor of reduced yield in crops is weed infestation (Cheema and Farooq, 2007).By releasing allelo-chemicals in the rhizosphere through roots and other plant parts, weeds reduce the grain yield (Reddy., 2001). Weeds may be considered more harmful than other pests because they not only cause loss to the crop yield but also make crop harvesting difficult. An increase in weed infestation decreases the grain yield. (Siddiqui and Shad, 1991). The grain yield of wheat is reduced up to 40-50% due to the weeds (Chaudhary *et al*., 2008). According to Bilalis *et al*.(2003) there is a need to shift to new practices for the effective control of weeds, which improve both environmental and economic conditions. Korres and Froud-Williams (2002) suggested that knowledge on the weed population and their species is quite essential, otherwise, the consequences may be the unsuccessful endeavour to control weeds. Nesterove and Chukanova (1981) found that maximum grain yield loss was due to the infestation of *Convolvulus arvensis*, *Amaranthus retroflexus*, and *Phalaris minor* was found as the predominating weed in wheat crop (Jalis, 1987). Among the different weeds species, *Phalaris minor* (grasses), and *Rumex dentatus*, and *Medicago denticulata* (broad-leaved weeds) were found to play important role in yield reduction under irrigated rice-wheat system (Chhokar *et al*., 2006; Singh *et al*.,1995; Balyan and Malik, 2000). The major grassy weed is *Phalaris minor* which is dominant in northern Indian (especially Haryana and Punjab). Most of the farmers in northern India mainly depend on herbicides (synthetics chemicals) to control *Phalaris Minor* in wheat crop, which is actually a very effective method as it is a cost-effective and time-saving practice. However, several incidences of herbicide resistance are reported frequently due to continuous and long-time use of single herbicide or herbicides, belonging to the same group (Beckie, 2006).

Phalaris minor is categorized as a noxious weed. It is one of the major and most destructive monocot weed in the wheat field, belonging to the grass family i.e., Poaceae which is similar to wheat, and thereby, the growth habit and development of *Phalaris minor* are very much similar to the wheat crop. As a consequence, it is difficult to differentiate wheat crop from *Phalaris minor* during its vegetative crop. Moreover, these weeds cause the partial shade to wheat crop due to their profuse tillering habit and deplete the crop growth. Some of the distinguishing features of *Phalaris minor* from the wheat crop are characterized as: the basal node of *Phalaris minor* is pinkish in colour whereas the basal node of wheat is greenish in colour, leaf colour of the weed is light yellow whereas the leaf colour of the crop is dark green, the tillers of *Phalaris minor* branch whereas the tillers of wheat do not branch, *Phalaris minor* produces 3000-4000 seeds per plant whereas wheat produces 60-70 seeds per plant and lastly, the seeds of *Phalaris minor* are much smaller than the wheat seeds and hence mixes easily with seeds of the main crop and creates a disturbance to the main crop. At present, a total of 22 species of *Phalaris* are recognized in the world. Studies state that it reached India through the import of wheat from North Africa. The average grain yield loss due to *Phalaris* is up to 25-50% but in severe infestation losses goes up to 80%. The surface moisture is important for the growth and development of this weed because the seedlings of this weed do not go deeper than 4-5 cm. The wheat field condition is usually congenial to fulfill this basic requirement of the weed and for this reason, the weed preferentially establishes in the wheat field. The optimum temperature required by *P. minor* is10 – 20 °C that is similar to that of wheat. The seeds of *P. minor* can remain in primary dormancy for about 3-4 months after maturity and in secondary dormancy for up to 12 months which may be one of the reasons for its better establishment in the wheat field. As far as its botany is concerned, this weed is a winter annual grass that is 25-70 cm tall and can grow up to 1 m, possessing fibrous roots. The stem is erect with branched tillers at the base. It has a fringed and membranous ligule and a slightly leathery leaf sheath. The inflorescence is known as spikelet which is an oblong or ovate panicle, 2-10 cm long and 1-2 cm wide. They have a huge seed production capacity.

At present, several practices could be adopted to control the weed population such as cultural methods, physical methods, mechanical methods, chemical methods, or biological methods. The majority prefers the chemical method since it is fast-acting and very effective. It also requires less labour and energy. But relying on chemical herbicides to control the weed population has led to detrimental effects on the ecosystem as well as human health. Therefore, instead of focusing on only chemical control measures, an integration of all the above-mentioned methods to control the weed population is considered a better option. Such an integration program is called integrated weed management (IWM). IWM combines the various long-term approaches such as physical, cultural, biological, and chemical control to maintain the weeds below the economic threshold level. The cultural control measures focus on manipulating the farm techniques to control the weeds such as crop rotation, choosing more competitive crops, increasing the seed rate and decreasing the row space, choosing high-quality seeds, using the shallow seedling technique, and many more. The physical or mechanical approaches are removal of weeds with hand or with the help of machines such as hand removal mowing and burning of the weeds. Biological methods include using of the natural enemies to control the weeds such as the use of *Zygogramma bicolorata* for the control of *Parthenium hysterophorus, Cactoblastis cactorum* (Cactoblastis moth) to control *Opuntia stricta* (Prickly pear) and rhizobacterial use for the control of *Phalaris minor* which affects seed germination (Phour and Sindhu (2018). The chemical methods include the use of chemical herbicides to control the various weeds. Herbicides work by speeding up or stopping or changing the weed's normal growth pattern, by drying out the body parts of weeds or by defoliating the plants. Care should be taken that the chemicals are used for appropriate crops, in appropriate quantities and at the appropriate time. There are three categories of herbicides available commercially. They are pre-planting herbicides, pre-emergence herbicides and post-emergence herbicides. Out of many issues, associated with the application of herbicides, herbicides-resistance is the major one. Herbicides can be applied by foliar spraying, basal spraying, stem injection, stump application, cut and swab, stem scrape and wick application. Also while applying herbicides various factors should be considered such as the possibility of rain, wind velocity, direction and nearness to water bodies. Overall, it is believed that the use of herbicides to control weeds should be reduced for a healthy ecosystem and healthy crop.

As *P. minor* is a noxious weed, it needs to be removed from the crop field and to do so farmers mainly depend on the various herbicides because herbicides are effective and fast acting but there are several reports that herbicides with their long time use have developed resistance in the weeds against that herbicide. One such case is isoproturon, in the 1980s isoproturon (Arenol) was suggested to control *Phalaris minor* and it worked for almost 10-15 years (Chhokar *et al*., 2012). Isoproturon was the most recommended herbicide since the late 90s. However, after almost a decade, the weed developed resistance against the herbicides due to continuous application of the same herbicide (Singh, 2007). It is usually applied 30-35 days after sowing. A recent study revealed that isoproturon, at the present day when applied at 1 and 2 kg a.i/ha, exhibited about 10.5% and 51.8% control of *Phalaris minor*, respectively which is relatively low as compared to the previous data (Chhokar *et al*., 2006). The isoproturon- resistance prone area is mainly distributed between Punjab, Haryana in Northern India. Isoproturon resistant *Phalaris minor* has caused a 65% reduction in the wheat grain yield in these areas (Chhokar and Sharma (2008). Many alternate herbicides with different mechanisms and mode of action were screened for the control of isoproturon resistant *Phalaris minor*. They were either applied alone or in combination with other herbicides. Application of post- emergence herbicide, flufenecet @180-480 g a.i/ha, applied at 15-21 days after sowing, showed a considerable amount of control but it was phytotoxic to the main crop (Varshney *et al*., 2012). The effect of the mixture of herbicides gradually is reduced at later growth stages of *Phalaris minor* at 4-5 leaves stage. Sulfosulfuron used as early post- emergence (19 DAS) and late post-emergence herbicide (30-42 DAS) @25-30 g a.i/ha, exhibited overall effectiveness. Hence, it may be concluded that sulfosulfuron is a better herbicide for weed control and crop yield. Herbicides are most effective in controlling the weeds. However, it is essential to use the herbicides very carefully; they will also, otherwise, develop resistance against the herbicides like isoproturon.

A significant interaction has been reported between wheat planting patterns and weed control measures. Bhan *et al*. (1982) conducted an experiment with cross row sowing and reported reduced weeds dry weight. Many other authors reported that a significant interaction between dates of sowing and weed control methods by adjusting sowing time in wheat crop, affects the germination of Phalaris because its peak germination period would not coincide with that of wheat crop (Chhokar and Malik (1999). Keil *et al*. (2015) suggested early sowing of wheat with zero tillage to give rise to significantly higher weed control and higher grain yield which consequently may increase productivity and net returns.

Considering the above facts, a study on **"Performance of herbicides to control *Phalaris minor* as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum*)"** was planned with the following objectives:

1. To study the interactive effect of date of sowing and weed control treatments on growth and development of weeds

2. To study the interaction between wheat planting patron and weed control measure on weed growth

3. To evaluate the effect of different sowing dates, planting patron and weed control measure on growth and yield attributing characteristics of wheat

4.* To study the efficacy of herbicides to control different biotypes of *Phalaris minor

CHAPTER: 2

Review of Literatures

2.1 : Effect of different sowing methods on the wheat crop

Crops differ in their yield responses with variations in their sowing methods. Bi-directional reflectance factors (BRFs) in the wheat crop show well-structured growth of the plant system which is heavily influenced by canopy design. It influences the growth and development of not only in wheat but also in many other crops (Zipoli and Grifont, 1994).
Ercoli and Masoni (1995) observed a decrease in the yield of grain with increasing spacing between rows; however, they found that the row orientations did not affect the crop yield. The uniform plant remains of wheat showed better use of sunlight, nutrients, and space which thus, applied a superior smothering impact on *Phalaris minor,* a problematic weed in wheat (Bhan and Kumar, 1997). Due to the close row spacing, the major weeds of wheat crop exhibited lesser dry matter accumulation under the smothering effect as opposed to the wider row spacing (Mahajan and Brar, 2001).

Sial *et al.*, (2001) noted that growing wheat crop at 15cm spacing and using a higher seed rate i.e., 150kg/ha improved the wheat grain yield because both closer spacing and higher seed rate increased the positive competition. Kappler *et al. (*2002) found that the different methods of sowing of wheat seeds affected the growth of the weeds. Mahajan *et al*.,(2002) conducted an experiment and found the positive effect of sowing wheat crop in both directions instead of sowing the crop in a single direction at a distance of 22.5 cm row to row (drill sowing). Ayub *et al*. (2008) conducted a field experiment with fennel seed crop and observed that the crops that were sown in line arrangement resulted in significantly higher seed yield due to higher seed number and umbels. The line sowing of the fennel in mid-October showed a maximum significant effect in the seed yield fennel.

Das and Yaduraju (2011) observed that leaving 20% of area unsown with defined planting pattern significantly increased the area of the leaf, number of leaves and ears, and nitrogen uptake by the crop. Results also revealed that weed density was decreased and foliage of wheat was increased. Jat *et al*. (2011) found that precision sowing of wheat and raising bed technique increased the grain yield by 16.66% and saved irrigation water up to 50% as compared to traditional methods (flat sowing and flood methods). Kahloon *et al.*, (2012) concluded that grain yield was increased by conservational sowing of rotary tillage drill method as compared to the traditional method. Mali and Choudhary (2013) carried out a study on sowing of the wheat crop at different row spacing (15, 17.5, 20, and 22.5 cm) and observed that the crops sown at 20 cm apart showed accumulation of highest dry matter but the other spacing like 17.5 and 15 cm showed lower dry matter in wheat. It was also observed that sowing of the crop with closer spacing reduced the crop yield due to an increase in competition.

Arif *et al*. (1997), conducting a field experiment on wheat, found that the cross sowing method showed a higher yield of grain (5.65 t ha^{-1}) and the seeds that were sown at 60×45 cm^2 apart in rows showed the lowest grain yield. Thus, it might be considered that spacing of 30x30 cm^2 with drill sowing gave a higher yield than all other treatments. This is due to various resources and their proper utilization. Chhokar *et al.,* (2012) stated that wheat might be infested with both grassy and broadleaf weeds and effective weed management might be required to control them below the threshold level. An integrated approach using both chemical and non-chemical approaches is one of the most effective one (Chhokar *et al.,* 2012). According to Idnani and Kumar, (2012), the yield contributing factors like test weight and ear head length were significantly higher in three row system as compared to traditional sowing in wheat crop.

Salam *et al*. (2013) demonstrated that wheat grown under deep tillage practice showed improvement in the physical properties of soil i.e. soil moisture, bulk density, etc. Noorka and Tabasum (2013) concluded that bed planting increased the grain yield by improving the proper aeration, root development, and high light penetration in the crop canopy. Farooq and Cheema (2014) established that out of three different types of wheat sowing, raised bed planting, drill sowing, and broadcasting, raised bed sowing increased the grain yield and reduced the weed population. Abdul Majeed *et al*. (2015) noted that wheat grown on beds improved fertilizer use efficiency, reduced crop logging, and increased the grain yield. According to Mollah *et al*. (2015), wheat grown on beds provided better results than conventional methods. The wheat grown on beds with 70cm of spacing resulted in 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 compared to flat sowing, which was nearly at par with the observations of Swelem *et al.* (2015). Swelem *et al*. (2015) demonstrated that sowing of wheat on raised beds with a spacing of 120 cm and application of nitrogen (180 kg/ha) increased nitrogen content and grain yield.

Devi *et al*. (2017) noted that sowing of wheat at 16 cm significantly decreased the weeds density and nutrient uptake by weeds. Results revealed that sowing of wheat at 18 cm increased the crop growth rate, grain yield and nutrient uptake by wheat crop. It was revealed that wheat grown with zero tillage with a spacing of 18cm exhibited high yielding tillers (Kamboj *et al*., 2017). Wheat grown with bed planter on beds showed longer spike lengths and higher test weight. It was observed that bed planting increased the production of cereals, pulses, and oilseeds than flat sowing (Tripathi and Das, 2017; Hussain *et al*., 2018). Hussain *et al*. (2018) noted that the wheat varieties of semi erect growth habit gave a good performance on beds in drained soils. The semi erect growth variety Aquab-2000 performed well with good yield when it was sown on beds with a 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.

2.2 : Effect of different sowing time

Tiwari (1990) found that delay in the time of sowing increased the infestation of weed (*Phalaris minor*) in comparison with early sowing of wheat crop. It might be due to a decrease in temperature which is more favorable for the growth of *Phalaris minor*. Kolar and Mehra (1992) reported that the density of *P. minor* was reduced when wheat was sown in October and December as compared to the sowing of wheat in November. They also mentioned the particular date i.e. 25^{th} November which was suitable for the sowing of wheat. On this date of sowing, not only weeds density was decreased but also the length of panicle and test weight of wheat seeds was increased.

Chester (1993) reported that the weed emergence and growth of the wheat crop is heavily influenced by the change in time of sowing. With the change in time of sowing, it reduced the weed competition and influenced the efficacy of herbicides. Kurchania *et al*. (1993) concluded that early sowing of wheat decreased the infestation of *Phalaris minor* as compared to normal sowing dates in the month of November. They also suggested that late sowing in the month of December led to a decreased density of *Phalaris minor* in wheat. Malik and Singh (1993) found that sowing of wheat at low temperature is more favourable for the emergence and growth of weeds which affected the crop badly with respect to its economic yield. In a different experiment, Yadav and Dahamn (2003) conducted a study at the Agricultural Research Station, Mandor (Jodhpur) during the winter season and found bathua (*Chenopodium album* L.), (*C. murale* L.) and Jungli palak (*Rumex dentatus* L.) as the major *rabi* weed species. The other weeds like wild onion (*Asphodels tenuifolius* Cav.), dhub grass (*Cyanodon dactylon* L.), and annual yellow sweet clover (*Melilotus indica* L.) were significantly affected by the different sowing time in the cumin crop. Duary and Yaduraju (2006) concluded that wheat yield decreased when it was grown in the mid of December. They noted that the density of *Phalaris minor* increased due to the late sowing of wheat. *Phalaris minor* reduced leaf area, number of tillers, ear bearing tillers, and grains per spike of wheat. Interestingly, Hussain *et al*. (2012) observed that early or late sown of wheat not only decreased the weed density but also decreased the grain yield as compared to normal sowing of wheat in November.

Mahajan *et al*. (2018) demonstrated a significant influence of sowing time over the quality of different rice cultivars. Sharif *et al*. (2019) noted that an increase in seed rate up to 125 kg/ha might increase the grain yield 4.24 t/ha and might decrease the weed population. Singh *et al*. (2019) observed that the temperature in November was more as compared to December. Low temperature (in December) was not suitable for *Phalaris minor* to germinate. For this reason, they suggested the sowing of wheat on 25th November that could increase the yield of wheat and decrease the density of *Phalaris minor*.

2.3: Combined effects of sowing methods with herbicide mixture on *Phalaris minor* in wheat crop

Balyan (2001)conducted an experiment in which the chemicals such as sulfosulfuron along with 0.1% of surfactant, isoproturon and combined mixture of metasulfuron methyl + isoproturon showed the significant result to control broadleaf weeds up to 52 to 88% and 55 to 85% control for grassy weeds. Use of metsulfuron methyl along with isoproturon (750+4 g/ha) also showed a similar result of crop production.

According to Sardana *et al.* (2001), the combination of 2,4-D and isoproturon followed by metribuzine at 175 g/ha resulted in a significantly more grain yield. It was observed that a combination of clodinafop (60g/ha) and fenoxyprop-p-ethyl (100g/ha) or combined application of clodinafop (60g/ha) with sulfosulfuron (25g/ha) controlled the *P.minor* completely. But interestingly, when the recommended dose (@ 940 g/ha) of isoproturon was doubled (1.88kg/ha), *P.minor* was not controlled (Brar *et al*., 2002). According to Singh *et al*., (2002), different types of weed flora and their density usually reduced 53% in grain yield in wheat crop. The different doses of sulfosulfuron i.e 20, 25, 30 and 45 g/ha controlled the weed density and found that 20g/ha or lower dose of sulfosulfuron had the lower capability to control the weed density. Sulfosulfuron @ 25 g/ha reduced density of weeds (more or less similar to weed free) up to 87% including weeds like *Avena ludoviciana*, *Phalaris minor,* and *Rumex retroflex*in and thus, contributing to high yield (Banga *et al.*, 2003)

Chahal *et al*. (2003) found that the integrated weed management induced significant results as compared to the application of herbicide alone. They noted that the population of *P. minor* and its dry matter accumulation reduced with deep tillage by mouldboard plough and close row spacing of 15 cm along with the application of clodinofop. The combined application of metsulfuron-methyl (3-4 g/ha) and 2,4-D (400 g/ha) induced a higher yield.
Jat *et al.* (2003) reported that sulfosulfuron (25g/ha) and metsulfuron- methyl (4g/ha) performed better than control. Kumar *et al*. (2003) found suppression of all types of weed density with the application of sulfosulfuron. Singh and Kundra (2003) reported that *Phalaris minor* in wheat was effectively controlled by sulfosulfuron and fenoxaprop and the grain yield of wheat using the herbicides, isoproturon, and fenoxaprop was almost similar.

Walia et al.(2003) observed reduced dry matter accumulation in *Phalaris minor*, using clodinafop and sulfosulfuron at their recommended level. They demonstrated that application of clodinafop @ 60g/ha were much effective in flat sown wheat crop as compared to bed planted crop. Tomar *et al.* (2004) also revealed that the dry matter production of weeds was significantly reduced by the various weed management treatments over the un-weeded control. The highest yield was observed in the application of isoguard followed by clodinafop + metribuzine. Chhipa *et al.* (2005) reported higher grain yield of wheat using metsulfuron-methyl (47.2 q/ha), and hand weeding (44.1 q/ha). Kumar *et al.* (2006) observed that the chemicals like sulfosulfuron, clodinafop, and fenoxaprop, when they were sprayed @ 25 g, 60 g, 120 g/ha in a volume of 250-500 l/ha, resulted in 89-91%, 92-93%, and 83-84% of weed (*P. Minor*) control, respectively. But when they were applied at lower rates, weed control was significantly reduced to 9%, 10%, and 18%, respectively. To increase the grain yield of wheat, herbicides at their recommended dose are usually applied and yield is increased by 21-29% in comparison with weedy control. Malik *et al.* (2005) conducted an experiment to evaluate the efficiency of herbicides like clodinofop, sulfosulfuron, and fenoxaprop against *P.minor*. The percentage of weed control was found to be 93%, 89%, and 83%, respectively, that increased the yield by 21-29% (Malik *et al* 2005). The unchecked growth of weeds resulted in a more than 36% reduction in yield. In another experiment, Walia *et al.* (2006) revealed that unchecked growth of weeds resulted in more than 36% of reduction in grain yield. They reported an increased grain yield by different herbicidal treatments.

Gopinath *et al.* (2007) revealed that herbicide application exhibited better results over the weedy check. Metribuzine @ 200 g/ha and sulfosulfuron @ 33 g/ha recorded lower weed dry weight as compared to the tank mix spray of isoproturon (750 g/ha) + 2, 4 –D (500 g/ha). A maximum benefit cost ratio and net return were recorded by metribuzine @ 250 g/ha followed by sulfosulfuron @ 33 g/ha. However, Jain *et al.* (2007), on the other hand, reported that zero tillage along with application of clodinafop followed by 2,4-D resulted in maximum benefit cost ratio. The application of sulfosulfuron and hand weeding gave similar results for the control of *Phalaris minor* (Pandey and Dwivedi, 2007). Verma *et al.,* (2007) observed that fenoxaprop-p-ethyl and sulfosulfuron decreased the weed density and increased nutrient availability for plants. The metsulfuron and sulfosulfuron were used as post-emergence herbicides and gave better yield (Zand *et al.*, 2007). The herbicides like sulfosulfuron and carfentrazone-ethyl (post-emergence) controlled all types of weeds (Upasani *et al.,* 2008). The grain yield of wheat was significantly reduced (43.63%) after the weed infestation throughout the cropping period (Verma *et al.*, 2008).

Walia and Gill (2008) reported that the major weed of wheat crop was *P .minor* and application of isoproturon and metoxuron were more effective than methabenzthiazuron. They also reported that the crop treated with herbicides gave more yield than the hand weeded crop. Ashrafi *et al.* (2009)observed that the application of herbicides for controlling both grasses and broadleaf weeds decreased density of weeds per sq. meter and increased spikelets/spike, grain yield, grain/spike, net income, and harvest index, as for instance sulfosulfuron+ metsulfuron 30g/ha. Brar and Walia *(*2009) observed a reduced dry matter accumulation in *Phalaris minor*, using mesosulfuron+iodosulfuron 12 g/ha and sulfosulfuron at its recommended level. They demonstrated that the application of a mixture of herbicide (mesosulfuron+iodosulfuron) @ 12 g/ha and sulfosulfuron 25g/ha was more effective than clodinafop @ 60 g/ha.

Dhawan *et al*. (2009) noted that the application of the same herbicides every year reduced the grain yield of wheat because *P. minor* became resistant to the herbicides. Clodinafop, sulfosulfuron, and fenoxaprop were used in the first year of field trial and were found to control the population of *Phalaris minor* efficiently with increasing grain yield. But the application of the same herbicides in the second year reduced the grain yield and *Phalaris minor* became resistant to the herbicides. Gill and Brar (2009) noted that the application of nitrofen as a pre-emergence herbicide gave effective control of *Phalaris minor* and also increased the yield of wheat crop. They also noted that the application of linuron, terbutryne, and dichlormate to eradicate *Phalaris minor* in wheat fields exhibited a phytotoxic effect on the wheat crop. It was observed that there was a 19.2% - 27.5% reduction in wheat yield. This was due to the competition of broadleaf weed, whereas due to grass weed the reduction in wheat yield was 33.2% - 43.7% (Shaban *et al.,* 2009). Brar and Walia (2010) reported that incorporation of rice crop residue combined with herbicides application had effective control on the *Phalaris minor*. They also noted that the application of clodinafop, sulfosulfuron, and metsulfuron + iodosulfuron significantly controlled *P. minor*. Saini and Walia (2010) observed that application of sulfosulfuron (25g/ha), pinoxaden (50g/ha), and idosulfuron + mesosulfuron (12 g/ha) as post-emergence treatment suppressed the density of *Phalaris minor* effectively than the control treatment, while Walia *et al.* (2010) observed that combination of carfentrazone along with sulfosulfuron and surfactant @ 750 ml/ha performed better results and combination of sulfosulfuron and metsulfuron reduced the density of *P. minor* and broadleaf weeds. It also increased the production of wheat crop. Meena and Singh (2011) reported that grain yield was significantly increased with application of herbicides in comparison with the weedy check. Marwat *et al.* (2011) found that herbicide application decreased weed biomass and enhanced the grains yield and yield contributing traits. Hesammi (2011) noted that grain yield was significantly reduced by *Phalaris minor* infestation with 20 to 80 plants per square meter. Sharma and Singh (2011) observed that the mechanical method of weed control at 15 and 30DAS led to the same results as obtained by application of sulfosulfuron (25g/ha). It was further demonstrated by the authors that mechanical weeding also significantly increased the yield of grains and uptake of NPK by wheat as compared to the weedy check. However, in another experiment, it was found that sulfosulfuron @ 20 g/ha led to higher grain yield as compared to weed free treatment (Singh *et al*., 2011).

Dry matter production, LAI, CGR, the number of spikes, no. of grains, and straw yield were significantly increased with an increase in the weed control treatments (Bharat *et al.*, 2012). Application of sulfosulfuron + 2,4-D, clodinafop + metsulfuron and fenoxaprop + metribuzine in tank mix gave maximum value. The highest cost-benefit ratio was observed in the combination of isoproturon with 2,4 D and the highest grain yield (5.05 t/ha) was observed in weed free treatments. 40.3% reduction in grain yield was observed in unchecked weed growth area (Bharat *et al.*, 2012).

Abbas *et al*. (2018) noted that integrated weed management was one of the effective methods to control *Phalaris minor*. They noted that the application of allelopathic mulches along with herbicides led to a satisfactory control of *Phalaris minor*. They used allelopathic mulch of rice, maize, sorghum, and sunflower crop. The post-emergence herbicides like sulfosulfuron, clodinafop, and metribuzine were used as chemical herbicide treatment in these cases. Prinsa *et al*. (2019) noted that the combination of herbicides was more effective than the application of single herbicides on *Phalaris minor*. They applied the combination of pendimethalin + metribuzine followed by metsulfuron + idosulfuron which helped in controllingresistant *P. minor*. Rasool *et al*. (2019) suggested that the application of flufenacet was helpful in the reduction of growth and density of *Phalaris minor* as compared to clodinafop. They reported that flufenacet was used to control multiple herbicide resistant *Phalaris minor*.Tarundeep *et al*. (2019) concluded that the application of pyroxasulfone was more effective than the application of sulfosulfuron, clodinafop, and pendimethalin for *P. minor* control. They reported that pyroxasulfone, a pre-emergence herbicide, was a suitable option for resistant *Phalaris minor* in wheat cultivation in Punjab.

2.4 : Effect of plant spacing on wheat crop

Chahal *et al*., (2003) noted that growing wheat at a close spacing of 15cm increased the number of tillers and decreased *Phalaris minor* population. The traditional sowing of wheat at the spacing of 22.5 cm imparted less grain yield as compared to the new technique of closer spacing. This planting technique gave 8% more grain yield. Olsen *et al*., (2005) found that the planting technique of sowing at close spacing 12.8 cm decreased the weed density and increased the grain yield. Kristensen (2008) observed that increased crop density and spatial uniformity decreased the crop-weed competition. The results showed that close spacing and N 80 kg/ha increased the yield of grain. Abbas *et al*. (2009) noted the performance of the drilled and conventional method (broadcasting) of sowing wheat. Their results revealed that the highest plant height was obtained under the drill method at 22.5 cm of spacing, whereas the highest grain yield was obtained under the broadcasting method.

Mali and Choudhary (2013) studied the performance of three wheat varieties i.e. GW332, GW336, and HI 1544. Results showed that the variety GW336 at recommended spacing gave better results. Amare (2014) noted that the application of chemical herbicide along with 15 cm spacing increased the yield of grain and decreased the population of weeds.

Ghafari *et al*.,(2017) studied the three row-spacing (20, 25, and 30cm) on different wheat varieties. The study revealed that the number of tillers and grain yield was more in 20 cm of spacing than 30 cm.

The row spacing of 15cm increased the yield and its components and decreased the population of weeds, application of herbicides like granstar+topik was found to increase the grain yield (El-Samie *et al*., 2018). Singh and Sharma (2019) conducted the experiment on four different row spacing and reported that bed sowing gave 10% to 14% higher grain yield than happy seeder and zero tillage sowing.

2.5 **: Efficacy of herbicides to control different biotypes of *Phalaris minor***

Dhaliwal *et al*., (1998) concluded that the control of *Phalaris minor* biotypes was reduced by using double the dose of isoproturon but application of fenoxaprop-p-ethyl, diclofop-methyl, and metribuzin significantly reduced the biotypes of *Phalaris minor*.. Brar *et al*. (1999) obtained maximum results by applying a higher dose of sulfosulfuron followed by fenoxaprop-p-ethyl and clodinafop. Diclofop methyl and tralkoxidim gave 100% control of *Phalaris minor*. All these herbicides had no phytotoxic effect. Singh and Kundra (2003) noted that the application of different herbicides i.e diclofop-methyl, sulfosulfuron, fenoxaprop, and pendimethalin controlled isoproturon resistant biotype of *P.minor*. Results showed that application of these herbicides significantly increased grain yield and yield contributing attributes. Chhokar *et al*., (2007) noted that *Phalaris minor* biotypes, which are resistant to isoproturon, reduced65% of grain yield. The mixture of herbicides gave a satisfactory result. The wheat grain yield was improved and isoproturon resistant *P. minor* was controlled by usage of post emergence herbicides clodinafop, fenoxaprop, pinoxaden, mesosulfuron, and sulfosulfuron.

Singh *et al*. (2011) reported that the application of metribuzine @210g/ha reduced the yield of wheat by 18% as compared to the application of a mixture of pinoxaden+ carfentrazone and application of accord plus (fenoxaprop+ metsulfuron) 275 g a.i./ha at 2-4 leaf stage gave 100% control of *Phalaris minor* but when applied at 4-6 leaf stage control 45 to 80% control of *Phalaris minor*. Yadav *et al*. (2016) concluded that clodinafop and sulfosulfuron did not improve the efficacy of *Phalaris minor*. Pinoxaden gave effective control over *P. minor* but not on broadleaf weeds. Results revealed that a mixture of clodinafop and sulfosulfuron followed by pendimethalin gave 90-100% control over *P.minor* and broadleaf weeds. The mixture of herbicides controlled the resistance behavior of herbicides in *Phalaris minor*. The application of post emergence herbicides clodinafop, fenoxaprop, and sulfosulfuron at 35 DAS did not give satisfactory results. Results showed that a mixture of mesosulfuron+iodosulfuron gave significant control of *Phalaris minor*. Results also showed that in the first year pinoxaden controlled 80% of *P.minor* and 55% in the second year. Rasool *et al*. (2019) reported that flufenacet controlled multiple herbicide resistant *Phalaris minor* Retz. in wheat. The application of flufenacet, which was an oxyacetanilide herbicide, at three different stages of wheat provided 85-90% of weed control, while the application of clodinafop resulted in only 39-40% reduction in biomass of *Phalaris minor*. The results showed that the application of flufenacet controlled the resistance of *Phalaris minor* as compared to clodinafop.

Abbas *et al*. (2017) conducted research on *Phalaris minor* which was a major weed of wheat and shows resistance against Acetyl-CoA carboxylase (ACCase) inhibitor. The chemical herbicide used for controlling *P. minor* was clodinaofop-propargyl, metribuzine, pinoxaden, sulfosulfuron and results revealed that all biotypes of *Phalaris minor* were resistant to fenoxaprop except PM-BWL-2. The mixture of herbicides controlled 50 to 80% of weeds. Kumar (2016) noted that *Phalaris minor* decreased the wheat yield, ranging from 5 to 50%. Isoproturon controlled the *Phalaris minor* for a long time till its resistance development. Application of clodinafop completely controlled the *Phalaris minor* at its recommended dose (60 g/ha). Abbas *et al*. (2016**)** concluded that fenoxaprop-p-ethyl was resistant to some biotypes of *Phalaris minor*. Among eight biotypes (PM-FS-1, PM-FS-2, PM-FS-3, PM-FS-4, PM-FS-5, PM-FS-6, PM-FS-7, PM-FS-8) four biotypes(PM-FS-1, PM-FS-2, PM-FS-6, PM-FS-7) of *Phalaris minor* was found to be resistant. The resistant biotypes showed less biomass reduction.

Roy *et al*. (2006) found that the alternative herbicide was clodinafop propargyl for the control of isoproturon resistant *Phalaris minor* biotypes. The herbicide clodinafop ester transformed to clodinafop acid. The clodinafop acid was more rapidly dissipated in wheat as compared to *Phalaris minor.* Smit *et al*. (2000) found that the weed *Phalaris minor* showed resistance towards ACC-ase inhibitors. The experiment was performed by taking three herbicides, diclofop-methyl, clodinaofop-propargyl, and iodosulfuron. From these three herbicides, two herbicides diclofop-methyl, clodinaofop-propargyl were ACC-ase inhibitors whereas iodosulfuron was ALS-inhibitor. Therefore, *Phalaris minor* showed resistance against diclofop-methyl and clodinofop-propargyl but iodosulfuron controlled the *Phalaris minor* significantly.

Balyan *et al*. (1999**)** also reported that fenoxaprop was an alternate herbicide to isoproturon for controlling resistant *Phalaris minor* biotypes. The fenoxaprop was applied alone or mixed with isoproturon and metsulfuron. The results revealed that metsulfuron was highly effective on broadleaf weeds. Combination of fenoxaprop with isoproturon significantly controlled isoproturon resistant biotypes. The isoproturon resistant biotypes required 8 to 11 times more dose of isoproturon for their control.

2.6 : Effect of sowing time, sowing methods, and application of herbicides on the nutrient uptake behavior of crops

Brar and Walia (2008) noted that the dry matter accumulation of *P. minor* was reduced by the application of post emergence herbicides clodinafop, sulfosulfuron, and a mixture of mesosulfuron + iodosulfuron and significantly increased grain yield and improved nutrient uptake by the wheat plant. Jat *et al*. (2013) noted that yield and yield components were affected by sowing time. Due to delay in sowing time, all these yield contributing characters were decreased. Results showed that maximum grain yield was observed under sowing of wheat on 20th November and lower grain yield was observed when wheat was grown on 23rd December.

Singh *et al*. (2017) concluded that a mixture of herbicides along with hand weeding significantly decreased the weeds dry matter and increased nutrient availability to crops. Use of herbicides also increased the availability of nutrients in the soil. Gaurav *et al*. (2018) found that wheat sown at raised beds had a lower accumulation of dry matter and less depletion of NPK by weeds. The application of atrazine reduced weed density followed by 2,4- D and increased the availability of NPKS and Zn for the wheat plant. Brar *et al*. (2019) concluded that organic carbon was not diverged by the application of herbicides. In fact, the availability of nitrogen, phosphorous, and potassium was improved by herbicides. The organic carbon and other nutrients in the soil were increased by zero tillage but it was decreased by burning of straw

CHAPTER 3

MATERIAL AND METHODS

The experiment was conducted during the *rabi* seasons of 2018-2019 and 2019-2020, at the fields of Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara on wheat (*Triticum aestivum*)under the program of "**Performance of herbicides to control *Phalaris minor* as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum)*"**. Three different field trials were designed in the split plot design. The details of the material and methodology adopted in the investigation 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 preparation, and different agronomical practices under the following sub-headings.

Experimental site description

Location of experimental site

The experiment was conducted at the University farm of Lovely Professional University, Phagwara, District Kapurthala during rabi season during 2018-2019 and 2019-2020. 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 is situated in Punjab and away from Delhi (capital of India) by 350 km-It falls under the sub-tropical region in the central plains of agro-climatic zone.

Climatic and weather condition

This experimental site under the subtropics regions remains cool in winter and hot in summer, providing rainfall in the month of July, August, and September due to the South-West monsoon. The temperature never goes below zero degree, however, especially in the months of December and January it remains extreme cold. The highest temperature is recorded as nearly 46 ^oC during the summer

Months of April, May, and June. Monsoon rains start in the second fortnight of July and become continuous 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 and data are shown in Fig. 3.1 – 3.4.The optimum temperature for wheat crop is 20 - 25^{0}C. It tolerates up to a maximum temperature of 35^{0}C. Normally wheat crop requires a cool climate with different temperatures at different growth phases.

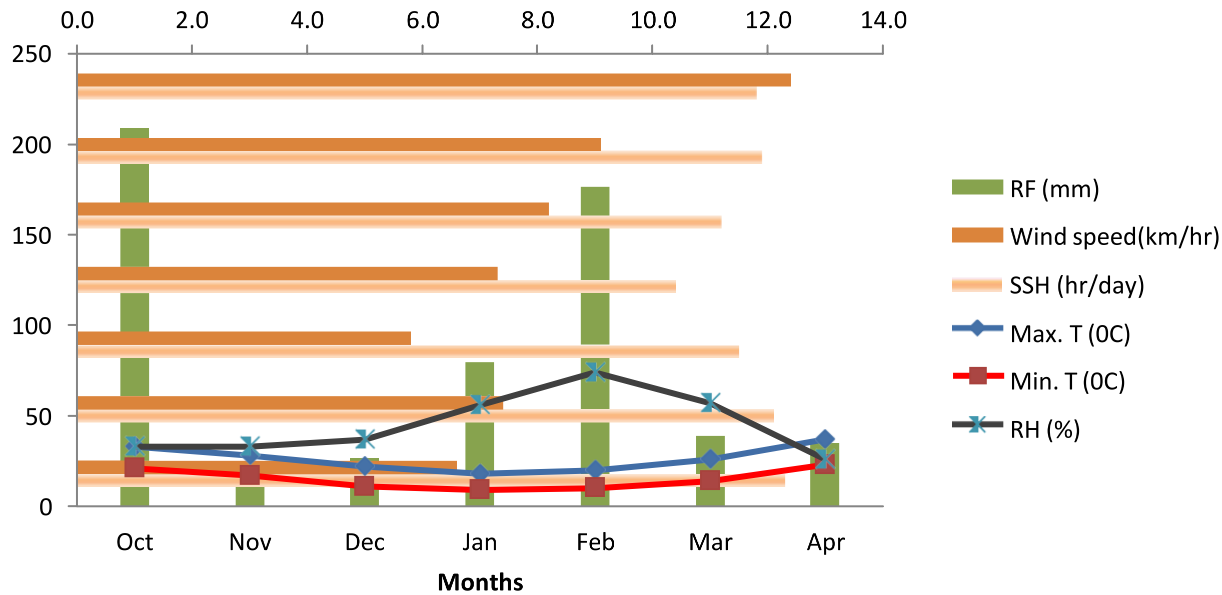


Figure.3.1. Temperature, wind speed, sunshine hour, relative humidity and rainfall conditions of experimental area 2018-2019

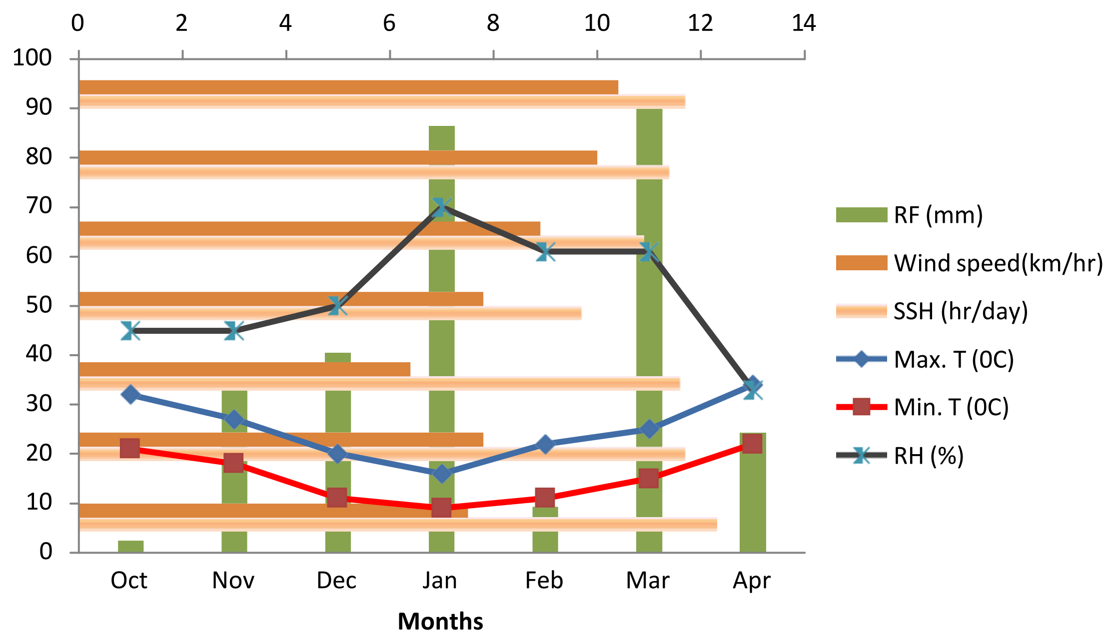


Figure.3.2. Temperature, wind speed, sunshine hour, relative humidity and rainfall conditions of experimental area 2019-2020

Soil sample collection

Before conducting the investigation, random samples of soil were collected from the field. After scraping the surface, v-shaped cut was made to depth of 6 inches and about 1-inch-thick slice of soil was collected from one side of cut. Similarly, 10 to 12 samples were collected from the field in zigzag direction. Finally, about 500 g soils were collected after mixing the soil samples uniformly through quartering method. The sample was used for checking the physical and chemical properties of soil. Initial soil fertility status of experimental site is shown in Table 3.1 and 3.2. At harvest, soil samples were again collected and analyzed.

Table.3.1. Physical properties of soil at experimental site

Characteristics	Percentage (%)
Sand content	68
Silt content	14.3
Clay content	15.7
Soil texture	Sandy Loam

Table.3.2. Chemical properties of soil at experimental site

S.no.	Particulars	Result	Method Followed
1	pH	7.6	pH meter
2	EC	0.31	EC meter
3	Organic carbon	0.45%	Walkley and Black`s method
4	Available Nitrogen	145kg/ha	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
5	Available phosphorus	13.8 kg/ha	Olsen method (Olsen *et a*., 1954)
6	Available potassium	168 kg/ha	Flame photometery method (Black, 1965)

Sources of nutrients used in the experiment

1) Urea (46% nitrogen).
2) Di-ammonium phosphate (46% phosphors)
3) Muriate of potash (60% potash)

History of cropping site

At the experiment site, rice –wheat rotation was followed for several years. Transplanted rice crop was sown as the previous crop before the experiment trial.

Details of experiment design

A split plot design was used with three different trials. First trial contained three main and five sub treatments, second trial contained four main and five sub treatments and third trial contained five main and six sub treatments with three numbers of replications each. Detailed numbers of treatments are presented in Table 3.3, 3.4 and 3.5.

Table 3.3. Treatment details of experiment first

Date of sowing	Treatment
D1	1^{st} November
D2	20^{th} November
D3	10^{th} December
Weed control treatment	
W1	Post em. application of sulfosulfuron 25g/ha.
W2	Post em. application of clodinafop 60g/ha followed by metsulfuron 5g/ha.
W3	sulfosulfuron + metsulfuron 30g/ha.
W4	Weed free check
W5	Weedy check (Control)

Table 3.4. Treatment details of second experiment

Method of sowing	Treatment
S1	Row to row spacing 15cm
S2	Row to row spacing 17.5cm
S3	Row to row spacing 22.5 cm
S4	Bi-directional sowing
Weed control treatment	
W1	Post em. application of sulfosulfuron 25g/ha.
W2	Post em. application of clodinafop 60g/ha followed by metsulfuron 5g/ha.
W3	sulfosulfuron + metsulfuron 30 g /ha.
W4	Weed free check
W5	Weedy check (Control)

Table .3.5.Treatment detail of third experiment

Bio types	Treatment
B1	Bio type 1
B2	Bio type 2
B3	Bio type 3
B4	Bio type 4
B5	Bio type 5
Weed control treatment	
W1	Sulfosulfuron
W2	Clodinafop
W3	Sulfosulfuron + metsulfuron
W4	Metribuzine
W5	Piroxofop-propanyl+ metribuzine
W6	Control

Table 3.6: Experiment details

Experiment 1	
Number of treatments	15
Number of replications	3
Number of plots	15 x 3 = 45
Experiment 2	
Number of treatments	20
Number of replications	3
Number of plots	20 x 3 = 60
Experiment 3	
Number of treatments	30
Number of replications	3
Number of plots	30 x 3 =90

Layout experiment: 1

MAIN WATER CHANNEL

6M

	R1		R2		R3	
3.5M	D3 T5		D2 T1		D1 T4	
	D3 T2		D2 T3		D1 T1	
	D3 T1		D2 T2		D1 T3	
	D3 T4		D2 T5		D1 T2	
	D3 T3		D2 T4		D1 T5	
	D2 T4		D1 T5		D3 T1	
PATH	D2 T1	WATER	D1 T2	PATH	D3 T3	WATER
	D2 T3	CHANNEL	D1 T1		D3 T2	CHANNEL
	D2 T2		D1 T4		D3 T5	
	D2 T5	1M	D1 T3		D3 T4	
	D1 T1		D3 T4		D2 T5	
	D1 T3		D3 T1		D2 T2	
	D1 T2		D3 T3		D2 T1	
	D1 T5		D3 T2		D2 T4	
	D1 T4		D3 T5		D2 T3	

Layout experiment:2

MAIN WATER CHANNEL

6M

	R1		R2		R3	
2.5M	M1 T5		M3 T3		M2 T4	
	M1 T2		M3 T5		M2 T1	
	M1 T1		M3 T4		M2 T3	
	M1 T4		M3 T1		M2 T2	
	M1 T3		M3 T2		M2 T5	
	M2 T1		M1 T4		M4 T5	
WATER CHANNEL	M2 T3	PATH	M1 T1	WATER CHANNEL	M4 T2	PATH
	M2 T2		M1 T3		M4 T1	55M
	M2 T5		M1 T2		M4 T4	
	M2 T4		M1 T5		M4 T3	
1M	M3 T4		M4 T1		M1 T3	
	M3 T1		M4 T3		M1 T5	
	M3 T3		M4 T2		M1 T4	
	M3 T2		M4 T5		M1 T1	
	M3 T5		M4 T4		M1 T2	
	M4 T3		M2 T5		M3 T1	
	M4 T5		M2 T2		M3 T3	
	M4 T4		M2 T1		M3 T2	
	M4 T1		M2 T4		M3 T5	
	M4 T2		M2 T3		M3 T4	

Layout experiment: 3

MAIN WATER CHANNEL							
		R1				2M	
B1 T1	1M	B2 T1	B3 T1		B4 T1		B5 T1
B1 T2		B2 T2	B3 T2		B4 T2		B5 T2
B1 T3		B2 T3	B3 T3		B4 T3		B5 T3
B1 T4		B2 T4	B3 T4		B4 T4		B5 T4
B1 T5		B2 T5	B3 T5		B4 T5		B5 T5
B1 T6		B2 T6	B3 T6		B4 T6		B5 T6
	WATER CHANNEL	R2		WATER CHANNEL			
B1 T3	0.5M	B2 T3	B3 T3		B4 T3	WATER CHANNEL	B5 T3
B1 T5		B2 T5	B3 T5		B4 T5		B5 T5
B1 T2		B2 T2	B3 T2		B4 T2		B5 T2
B1 T1		B2 T1	B3 T1		B4 T1		B5 T1
B1 T6		B2 T6	B3 T6		B4 T6		B5 T6
B1 T4		B2 T4	B3 T4		B4 T4		B5 T4
		R3				21M	
B1 T4		B2 T4	B3 T4		B4 T4		B5 T4
B1 T1		B2 T1	B3 T1		B4 T1		B5 T1
B1 T5		B2 T5	B3 T5		B4 T5		B5 T5
B1 T6		B2 T6	B3 T6		B4 T6		B5 T6
B1 T3		B2 T3	B3 T3		B4 T3		B5 T3
B1 T2		B2 T2	B3 T2		B4 T2		B5 T2

Figure.3.3 Experiment first (Date of sowing)

Figure.3.4 Experiment second (Method of Sowing)

Figure.3.5 Experiment third (Resistance of *Phalaris minor*)

Figure.3.6 *Phalaris minor* at panicle stage

Details of Variety:

Unnat PBW 343 was used in the experiment. It was released in 2017 and it is an improved variety of PBW 343. Height of PBW343 is about 100cm and it takes 155 days to attain maturity. The average grain yield is 23.2 quintals/acre. This variety is resistant to brown rust, moderately resistant to yellow rust but susceptible to loose smut. Unnat PBW 343 has been recommended by Punjab Agricultural University (PAU) to grow in Punjab.

Agronomic practices

Preparation of field:

Land preparation: Pre-sowing irrigation (rauni) was applied. Proper leveling of field was done for better irrigation efficiency. Field was ploughed three times: once with disk harrow and twice with cultivator followed by planking to ensure good germination.

Figure.3.7 Land preparation for wheat crop

Sowing time:

Normally sowing time of wheat is fourth week October to fourth week November for this variety. For first experiment sowing was done according to treatments (1st November, 20th number and 10th December). For second and third experiment, sowing was made in the first week of November**.**

Seed rate

Seed rate used was 100 kg/ha.

Method of sowing:

A row to row spacing of spacing of 22.5 cm is recommended for conventional sowing with about approximately depth of 4-6cm. For second trial, sowing was done according to treatments spacing (15, 17.5, 22.2 and bi-direction sowing). In bi directional sowing half quantity of seed rate was sown in one direction and half quantity of seed rate sown in perpendicular or across to first.

Figure.3.8. Sowing of wheat crop

Figure.3.9. Bi –directional sowing

Fertilizer application

Nutrient (kg/ha)		
Nitrogen (N)	**Phosphorus (P_2O_5)**	**Potassium (K_2O)**
125	**62.5**	**30**

The application of phosphorous and potassium was done in single split (basal application).Whole dose was applied at sowing time. Nitrogen was divided into three splits. First dose was given at the time of sowing. The other doses were done in two split doses before first and second irrigation.

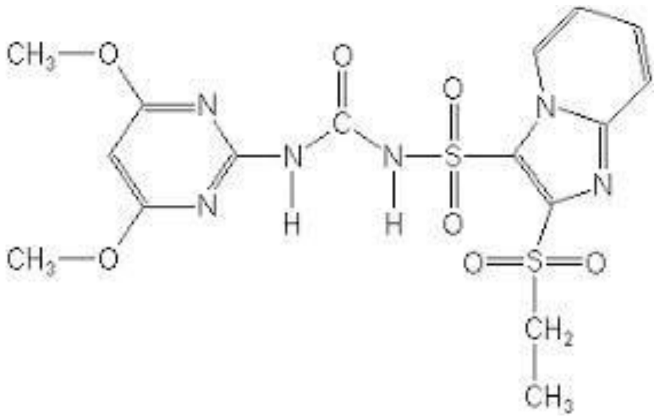
Weed management: According to treatments

Herbicide application

The herbicide was calculated according to its requirement and sprayed in required plot as per treatment with the help of knapsack sprayer.

Herbicide details

Sulfosulfuron



Common name : **Sulfosulfuron**

IUPAC : N-[[(4,6-dimethoxy-2-pyrimidinyl) amino] carbonyl]-2-(ethylsulfonyl) imidazo [1,2-a] pyridine-3-sulfonamide

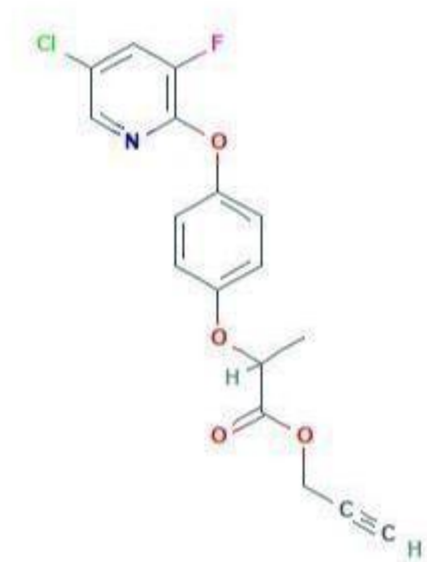
Formulation : 75-WG

Uses : Used post emergent herbicide for annual and broad leafs grasses.

Mode of action : It inhibits acetolactate synthase (ALS), which called acetohydroxyacid synthase (AHAS)ALS inhibition and low branched-chain amino acid production starts which result death of plant.

Clodinafop

Common name **:** Clodinafop-propargyl



IUPAC **:** prop-2-ynyl (2*R*)-2-[4-(5-chloro-3-fluoropyridin-2-yl) oxyphenoxy]propanoate

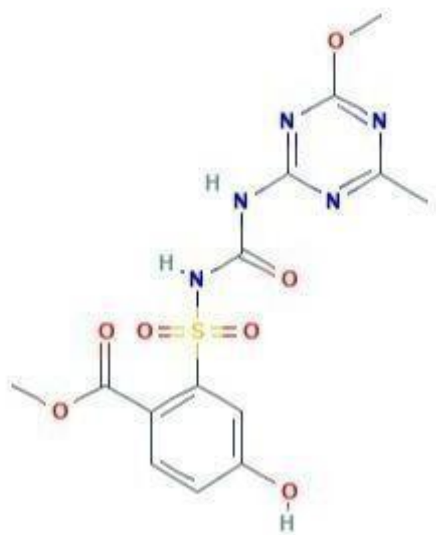
Formulation **:** 15-WG

Uses **:** It is used as post emergent herbicide for Phalaris minor, *Avena fatua*.

Mode of action: It is rapidly translocated in the plants and accumulates in meristematic tissues. It inhibits the enzyme acetyl CoA carboxylase (ACC-ase) and ceases the growth of plant.

Metsulfuron

Common name **: Metsulfuron-methyl**



IUPAC	**:** methyl 2-[(4-methoxy-6-methyl-1,3,5-triazin-2yl) carbamoylsulfamoyl]benzoate
Formulation	**:** 20-WP
Uses	**:** It is used as pre- and post-emergent herbicide for broad leaf weeds
Mode of action	: It acts as inhibitor of cell division in both roots and shoots of plant.

Metribuzine .

Common name : Metribuzine

IUPAC **:** 4-amino-6-tert-butyl-3-methylsulfanyl-1,2,4-triazin-5-one

Formulation	**:** 70-WP
Uses	**:** It is used as both pre- and post-emergent herbicide for annual grasses weeds.
Mode of action	: It acts as photosynthetic inhibitor in plant, resulting in death of plant

Irrigation:

Sow wheat after a heavy pre-sowing irrigation (10 cm) except when it follows rice. In case wheat sowing is likely to be delayed due to late harvesting of rice, the pre-sowing irrigation for wheat can be given to standing rice 5-10 days (depending upon soil type) before its harvest except where the crop is to be harvested with combine.. First irrigation was applied at 21 days after sowing. Next irrigation was applied during five to six weeks after the previous irrigation according to crop requirement. Last irrigation was provided at the end of March.

Plant protection:

For control of aphid, one spray of thiamethoxam 25 WG @ 20 g/acre was applied. Tebuconazole 25EC 200ml in 200 liter water were also applied in the end of February which resulted in an effective control against yellow rust.

3.5.6. Harvesting and threshing of crop:

The harvesting of crop was done manually plot wise when grains become hard and plant changes its color to yellow. Threshing was done manually by beating the stick. Grains were separated from straw by winnowing.

Treatment evaluation

Growth parameter:

1) Plant height:

Randomly five plants were selected from each plot and height was recorded with scale from ground level at 30, 60, and 90 DAS and at harvest.

2) Tillers number:

The number of tillers was recorded from one-meter row length from each plot at 30, 60, 90 DAS interval and expressed in number of tillers per square meter.

3) Dry Matter accumulation:

Dry matter accumulation of crop was recorded at 30, 60, and 90 days after sowing and at harvest of crop. Collect plant biomass was sun dried and then oven dried till constant weight.

Weed parameter:

1. **Height of *Phalaris minor*:**

   Phalaris minor height was recorded in cm at harvest by selecting ten random plants from each separate plot.

2. **Tillers count of *Phalaris minor*:**

   Tiller's count was recorded in one meter running row length.

3. **Number of leaves:**

   Numbers of leaves were counted at harvest by randomly selected ten plants from each plot.

4. **Panicles length of *P.minor:***

   At harvest random ten plant of were selected from each plot and average length were expressed in cm

5. **Number of Panicles:**

   The number of panicles was recorded at harvest stage from one meter running row length.

6. ***Phalaris minor* count:**

Weeds were identified and their counts were taken per square meter area. The weed density was expressed in number per square meter.

Figure.3.10. Data collection

7. *Phalaris minor* dry matter:

Dry matters of weeds were measured after drying the counted number of weeds.

8. Weed control efficiency (WCE):

WCE was estimated by using the following formula:

WCE= (X-Y)/X *100

Where x = weed dry weight in weedy check and y = weed dry weight

Yield parameters:

1. **Number of effective tillers :**

   Numbers of effective tillers were counting from one meter row length in each plot and expressed in number of effective tillers per square meter.

2. **Length of ear (cm):**

   Ten ears were selected randomly. Length of ear was measured with scale by selecting ear randomly.

3. **Grain per ear:**

   After randomly selecting the ten ear from each plot, numbers of grains were recorded simply by counting and averaged the number of grains per ear.

4. **1000 grain weight (g):**

   1000 grains were taken by counting from seed lot and weight was recorded by using weighing balance.

5. **Grain Yield per hectare (kg):**

   Each plot was harvested and threshed separately and after that, yield was recorded and converted into the quintal per hectare.

6. Straw yield per hectare (kg):

Separately from each plot after threshing grains, straw yield was recorded with the help of weighing balance.

7. Harvest index (HI) :

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

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

Statistical analysis

The data were analyzed by OPSTAT at level of 95 % significance to check the influence of different variables.

Figure.3.11. Tillering stage status of crop

Figure.3.12. Grain filling stage

Figure.3.13. Bio types of *Phalaris minor*

Figure.3.14. Herbicide application at 30 DAS

Figure.3.15. Crop at maturity

Figure.3.16. Advisor visit at field

RESULTS AND DISCUSSION

The present study, entitled "**Performance of herbicides to control *Phalaris minor* as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum)*",** was conducted in the experimental field of Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara during the Rabi season of 2018-2019 and the field experiment was again repeated in the next *rabi* season 2019-2020. The important findings of the experiments have been discussed under the following sub-headings experiment wise.

Experiment: 1 Effect of date of sowing and weed control treatments on growth and development of plants and weeds.

4.1.1 Plant height

The most important parameter for governing crop yield is plant height. Data on periodic plant height recorded during 2018-2019 are shown in Table (4.1.1a). The difference in height of plants was due to sowing dates and it was found to be non-significant when recorded at 30 DAS. The plant heights recorded at 60 DAS, 90 DAS and at harvest were found to be significantly higher in its first date of sowing i.e. 1st November, in comparison with crop sown on 20th November and 10th December. However, the plant height of crop sown on 20th November was found to be significantly more than that of 10th December sown crop. The first date of sowing (1st November) was found to be a felicitous sowing time. This may be due to the better utilization of light, nutrients, and moisture (Akdamar *et al*., 2018).

Among weed control treatments, the difference in plant height was non-significant when recorded at 30 DAS in comparison with other treatments as the herbicide was applied at 30 DAS (Table 4.1.1a). All weed control treatments significantly exerted higher plant height as compared to unweeded (control) treatment when recorded at 60, 90DAS and at harvest in accordance with Nanher and Raghuvir (2015). Among herbicidal treatments, significantly higher plant heights were recorded at all periodic intervals (except 30 DAS) with the application of mixture of sulfosulfuron + metsulfuron @ 30g/ha as compared to the application of sulfosulfuron @ 25g/ha and clodinafop @ 60g/ha followed by metsulfuron @ 5g/ha. Significantly smaller plants were recorded in weedy check due to the more density of weeds. Higher plant height might be due to better utilization of resources like plant growth nutrient, light, and moisture and less competition with the weeds. Weed free environment encourages more growth of plant in weed free treatment, which results in significant increase in plant height in comparison with a weedy check. The interactive effects of sowing time and different weed control treatment were found to be non-significant for plant height. The periodic height recorded during 2019-20 crop season has been shown in Table 4.1.1b. Similar trends were observed in both years 2018-2019 and 2019-2020. Crop sown on November 1st, 2019 recorded significantly higher plant height than other dates of sowing. Also, among sub-plot treatments, the application of sulfosulfuron + metsulfuron was found to record significantly higher plant height than other herbicidal treatments at all periodic intervals

Table 4.1.1. Effect of date of sowing and different weed control treatment on plant height during 2018-19 and 2019-20

Plant heights (cm) during 2018-2019 and 2019-20								
	30 DAS		**60 DAS**		**90 DAS**		**At harvest**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Dates of sowing								
D1 (1 November)	26.81	26.61	58.01	58.34	93.36	93.67	98.81	98.20
D2 (20 November)	26.59	26.44	56.91	57.08	92.50	92.57	97.71	96.86
D3 (10 December)	26.53	26.38	53.96	54.12	89.44	89.69	94.76	93.93
CD 5%	NS	NS	0.59	0.62	0.55	0.855	0.63	0.741
Weed control treatment								
Sulfosulfuron 25g/ha	26.70	26.59	56.82	56.59	92.32	92.48	97.62	96.59
Clodinafop 60g/ha followed by metsulfuron 5g/ha	26.56	26.40	55.41	55.47	90.79	91.05	96.21	95.76
Sulfosulfuron + Metsulfuron 30g/ha	26.64	26.34	58.24	58.61	93.74	93.99	99.04	98.59
Weed free	26.51	26.23	59.05	59.54	94.46	94.72	99.85	99.06
Weedy check	26.80	26.81	51.96	52.35	87.51	87.64	92.76	91.66
CD 5%	NS	NS	0.55	0.83	0.53	0.687	0.54	0.313
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

4.1.2 Tiller number per meter (row length)

The number of tillers per unit area is considered as major determinants for the crop growth and yield. The data pertaining to the number of tillers, recorded at 30, 60, 90 DAS and at harvest stage, are presented in Table (4.1.2a and 4.1.2b). The data recorded at 30 DAS showed that there is no significance difference between sowing time treatments and different weed control treatments. However, numbers of total tillers differ significantly at 60, 90 DAS and at harvest stage. It had been found that the tillers in both years recorded at 60,90 DAS and at harvest was significantly higher in sowing of crop on 1st November as compared to the crop sown on 20th Nov and 10th Dec. This was due to congenial climate conditions. Significantly more no. of tillers at 60 ,90 DAS and at time of harvest were found in weed free treatment as compared to others and it was followed by sulfosulfuron + metsulfuron @ 30g/ha, sulfosulfuron @ 30g/ha and clodinafop60 g/ha followed by metsulfuron @ 5g/ha. These observations hold good for both the years. Application of post emergence sulfosulfuron + metsulfuron 30g/ha during both years produced significantly higher total tillers than other herbicidal treatments. From all treatments significantly least number of tillers was recorded, while they were compared with weedy check (control treatment).This was due to proper utilization of nutrient, light, moisture and other resources in weed control treatments. The interactive effects of date of sowing and different weed control treatments were found to be non-significant. Similar trends were found in both years, 2018-19 and 2019-20.

Table 4.1.2. Effects of date of sowing and different weed control treatments on number of tillers during 2018-2019 and 2019-20

Number of tillers per square meter (cm) during 2018-2019 and 2019-20								
	30 DAS		60 DAS		90 DAS		At harvest	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Dates of sowing								
D1 (1 November)	163.64	165.77	344.04	345.02	436.97	435.95	426.75	425.11
D2 (20 November)	162.62	164.8	340.71	341.15	431.6	431.02	419.42	419.77
D3 (10 December)	162.35	164.48	317.37	316.71	418.84	418.13	406.08	406.66
CD 5%	NS	NS	10.93	12.4	4.31	1.28	2.97	2.66
Weed control treatment								
Sulfosulfuron 25g/ha	163.11	165.24	332.26	334.88	429.86	429.42	418.35	417.95
Clodinafop 60g/ha followed by metsulfuron 5g/ha	162.48	164.62	332.17	334.53	425.55	425.77	413.55	415.2
Sulfosulfuron + Metsulfuron 30g/ha	162.84	164.97	350.57	349.64	438.66	438.26	426.35	427.68
Weed free	162.311	164.48	356.84	352.84	441.95	440.22	431.37	429.86
Weedy check	163.6	165.73	299.55	299.68	409.68	408.22	397.55	395.28
CD 5%	NS	NS	17.77	14.44	2.48	1.06	3.02	1.511
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

4.1.3 Accumulation of dry matter

Dry matter accumulation 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 accumulation is shown in Table (4.2.3a and 4.2.3b). Different dates of sowing were non-significant at 30 DAS. Data recorded at 60 DAS, 90 DAS and at harvest were found to be significantly higher at first date of sowing i.e. 1^{st} November as compared crop sown on 20^{th} November and 10^{th} December during both year of study (2018-19 and 2019-20). Crop dry matter accumulation was significantly affected by different weed control treatment at 60 DAS, 90 DAS and at harvest. Data recorded at 30 DAS was found to be a non-significant, because herbicide application was done at 30 DAS. Weedy check produced lowest dry matter accumulation than all other weed control treatments. Weed free treatment was found to produce highest dry matter accumulation at 60 DAS, 90 DAS and at harvest which may be due to better weed free environment that helps the crops to attain better accessibility to available nutrients and moisture. The data conforms previous reports (Ahamad *et al*., 1993; Chopra and Chopra, 2005 and Punia *et al*., 2011). From the different herbicidal treatments sulfosulfuron + metsulfuron 30g/ha produced significantly higher dry matter accumulation as compared to sulfosulfuron 25g/ha and clodinafop 60g/ha followed by metsulfuron 5g/ha. The date of sowing and weed control treatments had found no interaction. Similar result-pattern was observed during both years (2018-19 and 2019-20).

Table 4.1.3. Effects of date of sowing and different weed control treatments on plant dry matter production during 2018-19 and 2019-20

Dry matter production (g/m^2) during 2018-19 and 2019-20								
	30 DAS		60 DAS		90 DAS		At harvest	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Dates of sowing								
D1 (1 November)	21.07	21.53	261.49	262.77	591.80	596.00	1058.15	1068.55
D2 (20 November)	20.71	21.02	259.83	261.46	583.89	588.08	1050.33	1061.63
D3 (10 December)	19.80	20.27	257.29	258.50	578.55	582.74	1042.76	1053.10
CD 5%	NS	NS	1.61	1.55	3.329	3.66	6.70	6.99
Weed control treatment								
Sulfosulfuron 25g/ha	20.44	20.68	261.15	262.88	586.02	590.58	1052.16	1062.93
Clodinafop 60g/ha followed by metsulfuron 5g/ha	20.16	20.90	260.85	261.78	584.71	588.91	1050.60	10.61.27
Sulfosulfuron + Metsulfuron 30g/ha	20.29	21.36	262.14	263.62	590.07	594.27	1056.17	1066.84
Weed free	20.74	21.53	263.34	264.88	594.24	598.43	1058.36	1068.77
Weedy check	21.00	20.22	250.19	251.39	568.69	572.88	1034.79	1044.65
CD 5%	NS	NS	1.32	0.93	3.18	3.18	3.57	3.48
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

4.1.4 *Phalaris minor* count

Phalaris minor infestation in the cropped field directly influences the total crop yield, this is why, in the present investigation, *P.minor* counts at periodical intervals were monitored for different treatments to evaluate their efficiencies in boosting the crop yield. Counts of *Phalaris minor* were recorded periodically at 30 , 60, 90 DAS and at harvest as shown in Table 4.4.a and 4.4.b. Dates of sowing were found to affect the weed density significantly. Less number of *P.minor* per sq. meter was observed for first date of sowing (1^{st} November) in comparison with 2^{nd} date of sowing (20 November) and 3^{rd} date of sowing (10 December). This might be due to unfavorable climatic conditions for germination of *P. minor* on November 1^{st} than other dates of sowing. Ideal temperature for germination of *Phalaris minor* was reported to be 17 – 20 ^{o}C (Singh and Ghosh 1982). The non- significant effects on *P.minor* population (30 DAS) were exerted by various weed control treatments as the herbicides were applied at 30 DAS. *P.minor* population was significantly higher in weedy check. *P.minor* population was found to be zero in weed free treatment**.** Treatments of sulfosulfuron + metsulfuron 30g/ha produced significantly a smaller count of *P.minor* than that of sulfosulfuron 25g/ha and clodinafop 60g/ha followed by metsulfuron 5g/ha. At 60, 90 DAS and at harvest, application of sulfosulfuron 25g/ha was found to be significantly higher than clodinafop 60g/ha + metsulfuron 5g/ha with respect to *P. minor* count.

Table4.1.4a. Effects of date of sowing and different weed control treatments on *P. minor* count during 2018-19 and 2019-20

***P. minor* count per square meter during 2018-19 and 2019-20**								
	30 DAS		**60 DAS**		**90 DAS**		**At harvest**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Dates of sowing								
D1 (1 November)	49.55	75.73	20.18	25.01	19.19	23.41	20.23	25.03
D2 (20 November)	73.96	97.36	23.16	31.12	22.02	28.00	23.34	30.97
D3 (10 December)	75.59	98.82	30.04	34.59	25.60	31.92	26.75	34.52
CD 5%	1.79	2.38	1.10	2.01	1.95	1.12	2.00	1.45
Weed control treatment								
Sulfosulfuron 25g/ha	67.25	91.73	11.38	19.63	10.81	17.51	11.17	20.93
Clodinafop 60g/ha followed by metsulfuron 5g/ha	66.31	91.36	13.65	21.20	12.82	20.29	13.19	23.67
Sulfosulfuron + Metsulfuron 30g/ha	65.33	90.13	8.14	11.11	9.59	13.77	9.89	17.60
Weed free	66.96	91.41	0.0	0.0	0.0	0.0	0.0	0.0
Weedy check	65.98	88.55	89.15	99.33	78.13	87.31	82.97	88.66
CD 5%	NS	NS	1.20	1.96	1.62	1.33	1.84	1.24
CD interaction	NS	NS	2.21	3.64	3.06	2.43	3.44	2.35

The interactive effect was found to be significant in between date of sowing and weed control treatments. Herbicides sulfosulfuron + metsulfuron 30g/ha decreased *P. minor* population significantly at all dates of sowing in comparison to herbicide treatments with sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha. Same results were found during both years of investigation. However, in the case of application of sulfosulfuron + metsulfuron 30g/ha, the crop sown on 10th December recorded more population of *P.minor* as compared to crop sown on 20th December. But the count of *P.minor* was not influenced with date of sowing under the application of sulfosulfuron @ 25g/ha and clodinafop @60g/ha followed by metsulfuron 5g/ha treatments. Interaction data of *P.minor* is shown in Table 4.2.4c.

Interaction data of *P. minor* during 2019-20 are presented in Table 4.2.4d. The count of *P. minor* was found to be statistically at par in crops sown on 20th November applied with sulfosulfuron + metsulfuron 30g/ha as compared to that of sulfosulfuron 25g/ha applied crops sown on 1st November. Application of clodinafop 60g/ha followed by metsulfuron 5g/ha on 20th December sown crop recorded significantly higher *P.minor* count than the application of sulfosulfuron 25g/ha and sulfosulfuron + metsulfuron 30g/ha on all the three dates of sowings.

4.1.4b. Interaction among different date of sowing and different weed control treatments on *phalaris minor* count during 2018-19

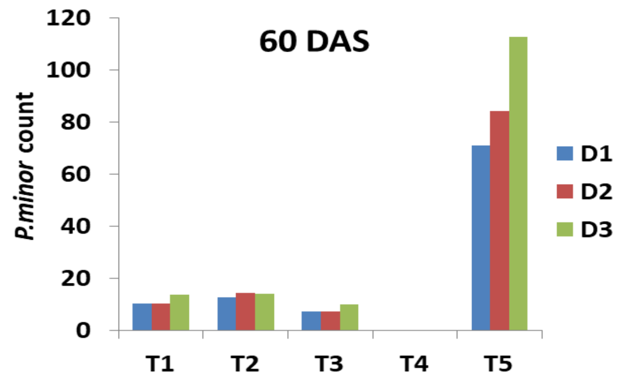
Treatment	sulfosulfuron 25g/ha	clodinafop 60g/ha followed by metsulfuron 5g/ha	sulfosulfuron + metsulfuron 30g/ha	Weed free	Weedy check	Mean
60 DAS						
1st November	10.18	12.58	7.34	0.00	70.79	20.18
20th November	10.20	14.26	7.30	0.00	84.07	23.16
10th December	13.74	14.11	9.78	0.00	112.60	30.04
Mean	11.38	13.65	8.14	0.00	89.15	
CD 5%	**2.21**					
90DAS						
1st November	9.24	11.70	7.95	0.00	67.05	19.19
20th November	10.57	13.10	8.95	0.00	77.50	22.02
10th December	12.62	13.68	11.89	0.00	89.83	25.60
Mean	10.81	12.82	9.59	0.00	78.13	
CD 5%	3.06					
At harvest						
1stNovember	9.80	12.19	8.17	0.00	71.01	20.23
20th November	11.21	13.50	9.39	0.00	82.62	23.34
10th December	12.51	13.88	12.10	0.00	95.29	26.75
Mean	11.17	13.19	9.89	0.00	82.97	
CD 5%	3.44					

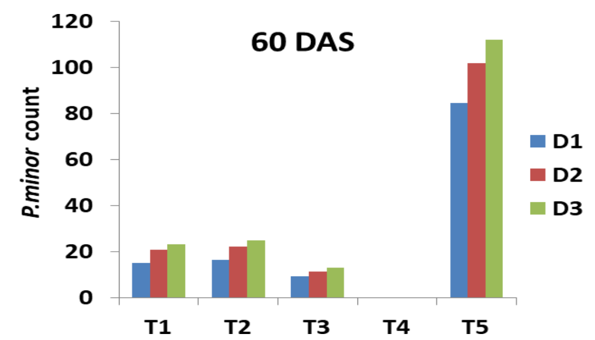
4.1.4 c. Interaction among different date of sowing and different weed control treatments on *phalaris minor* count during 2019-20

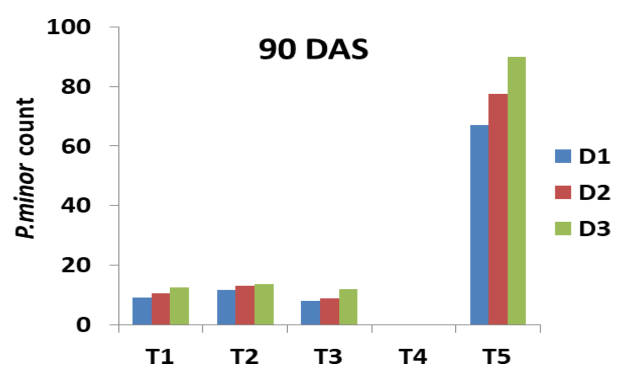
Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
60 DAS						
1st November	15.18	16.52	9.11	0.00	84.43	25.05
20th November	20.66	22.16	11.16	0.00	101.63	31.12
10th December	23.05	24.91	13.06	0.00	111.94	34.59
Mean	19.63	21.20	11.11	0.00	99.33	
CD 5%	3.64					
90DAS						
1st November	13.93	16.85	11.13	0.00	75.15	23.41
20th November	17.46	19.88	12.93	0.00	89.73	28.00
10th December	21.15	24.16	17.26	0.00	97.04	31.92
Mean	17.51	20.29	13.77	0.00	87.31	
CD 5%	2.43					
At harvest						
1st November	16.76	19.17	14.11	0.00	75.10	25.03
20th November	21.82	23.01	17.75	0.00	92.30	30.97
10th December	24.22	28.83	20.95	0.00	98.60	34.52
Mean	20.93	23.67	17.60	0.00	88.66	
CD 5%	2.35					

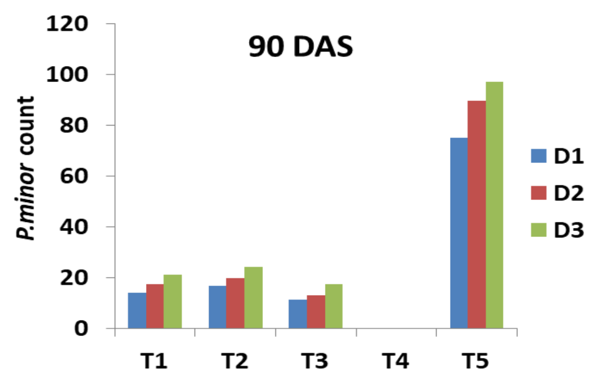
Fig .4.1 Interactive effect of date of sowing and different weed control treatment on *Phalaris minor* count during year 2018-19 and 2019-20

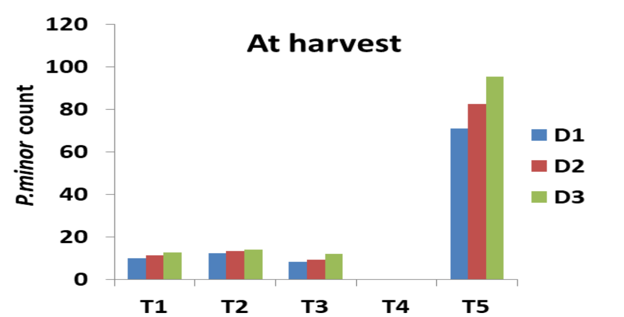
2018-19	2019-20

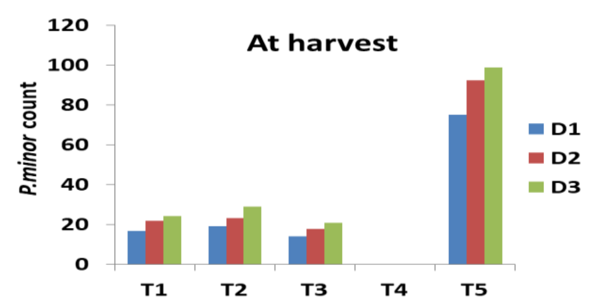












D1: November 1st ,D2: November 20th , D3: December 10, T1: sulfosulfuron 25g/ha, T2: clodinafop60g/ha fb metsulfuron 5g/ha, T3:sulfosulfuron 30g/ha, T4: weed free, T5: weedy check

4.1.5 Dry matter (DM) accumulation of *P. minor*

In Table 4.1.5a.and Table 4.1.5b, the data recorded at 30, 60 and 90 DAS and at harvest of *Phalaris minor* (DM) are presented. It was observed that in the case of 1^{st}November date of sowing, weeds accumulated significantly less DM with respect to sowing dates of crop at 20^{th} November and 10^{th} December. At 30 DAS, *P.minor* DM accumulation in the case of second date of sowing (20^{th} November) and third date of sowing (10^{th} December) was found to be statically at par. However, at 60, 90 DAS and at harvest, data showed that sowing of crop on November 1^{st} recorded less DM in comparison with other sowing dates (20^{th} Nov and 10^{th} Dec). Similar trends were found in both years 2018-19 and 2019-20.

Significantly highest DM was observed in weedy check. At 60, 90 DAS and at harvest, application of sulfosulfuron + metsulfuron 30g /ha showed a significant reduction in DM accumulation with respect to treatment of sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha. At 90 DAS, herbicide treatment clodinafop 60g/ha + metsulfuron 5g/ha and sulfosulfuron 25g/ha were statistically at par. The interaction between dates of sowing and weed control treatments was found to be significant (Table 4.1.5c. and Table 4.1.5d)

At 60 DAS, interaction data of *P.minor* DM accumulation indicated that application of sulfosulfuron + metsulfuron 30g/ha was statistically at par at all dates of sowing but produced significantly less DM than application of clodinafop 60g/ha followed by metsulfuron 5g/ha and sulfosulfuron 25g/ha. From various weed control treatments, data recorded at 90 DAS and at harvest showed significantly less DM accumulation in crop sown on November 1^{st} than the crop sown on 10^{th} December. Application of sulfosulfuron + metsulfuron 30g /ha produced significantly less DM of *P. minor* in 1^{st} November sown crop as compared to other herbicidal treatments on all dates of sowing during 2019-20.

Table 4.1.5a. Effects of date of sowing and different weed control treatments on *P. minor* dry matter production during 2018-19 and 2019-20

P. minor dry matter production g/m^2 during 2018-19 and 2019-20								
	30 DAS		**60 DAS**		**90 DAS**		**At harvest**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Dates of sowing								
D1 (1 November)	8.48	12.75	10.78	13.20	17.34	21.38	19.79	24.54
D2 (20 November)	12.58	16.29	12.29	16.37	19.78	25.46	22.77	30.12
D3 (10 December)	12.79	16.41	15.94	18.21	22.93	28.98	26.03	33.16
CD 5%	0.51	0.42	0.44	0.81	1.40	0.94	1.98	1.53
Weed control treatment								
Sulfosulfuron 25g/ha	11.41	15.32	6.44	10.33	10.92	17.53	10.75	20.85
Clodinafop 60g/ha followed by metsulfuron 5g/ha	11.30	15.26	7.15	11.16	11.37	18.19	12.88	22.40
Sulfosulfuron + Metsulfuron 30g/ha	11.20	15.09	4.28	5.84	8.511	12.35	9.66	17.09
Weed free	11.29	15.21	0.00	0.00	0.00	0.00	0.00	0.00
Weedy check	11.22	14.88	47.15	52.31	69.29	78.30	81.03	86.02
CD 5%	NS	NS	0.95	1.40	2.01	1.91	1.74	1.51
CD interaction	NS	NS	1.68	2.48	3.62	2.74	3.27	2.81

Interaction data of *P. minor* DM accumulation during 2018-19 are shown in Table 4.1.5c. It was found that DM accumulation under combined application of sulfosulfuron + metsulfuron 30g/ha was statistically at par with all dates of sowing but significantly differed from other herbicide applications such as clodinafop 60g/ha + metsulfuron 5g/ha and sulfosulfuron 25g/ha. However, application of sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha in 1st November sown crop were found to be statistically at par with each other at 60 DAS in respect of DM accumulation. Similarly, data recorded at 90 DAS showed application of post emergence sulfosulfuron + metsulfuron 30 g/ha were at par in crop sown at 1st November and 20th November but statistically significant from crop sown 20th December in reducing DM content. At harvest, interaction data indicated that herbicide treatment sulfosulfuron + metsulfuron 30 g/ha on 1st November crop produced significantly lower DM of *P. minor* than that of 10th December sown crop. However, the effects of treatment with sulfosulfuron 25g/ha and clodinafop 60g/ha followed by metsulfuron 5g/ha remained same on all the dates of sowings.

Interaction data of *P. minor* DM accumulation during 2019-20 are shown in Table 4.1.5d. At 60 DAS, interaction data of *P. minor* DM accumulation indicated that the effects of the treatment of sulfosulfuron + metsulfuron 30g/ha were statistically at par at all dates of sowing but the treatment produced significantly less dry matter than the treatment of clodinafop 60g/ha + metsulfuron 5g/ha and sulfosulfuron 25g/ha. Data recorded at 90 DAS and at harvest showed that DM accumulation in crop sown on 1st November was significantly lower than that of the crop sown on 10th December. Application of combination of sulfosulfuron + metsulfuron 30g /ha produced significantly less DM of *P. minor* in 1st November sown crop as compared to other herbicidal treatments on all dated of sowing during 2019-20:

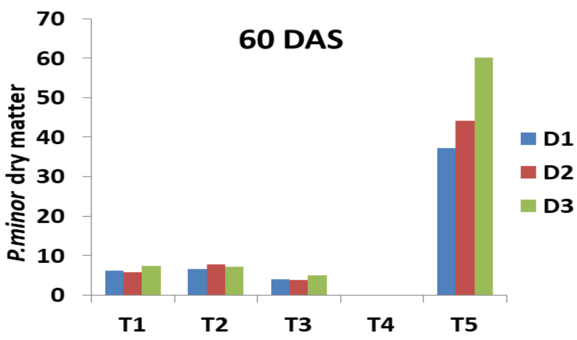
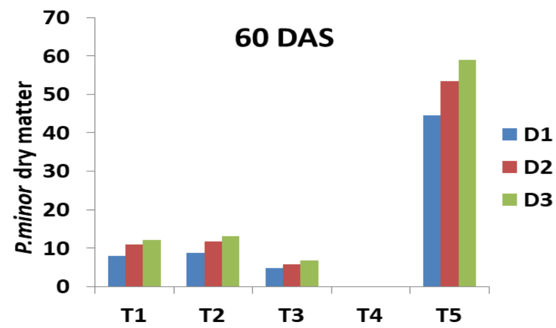
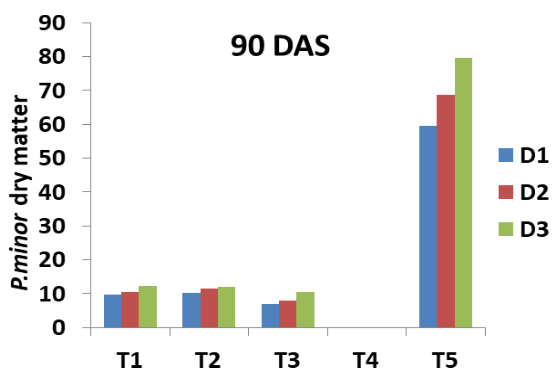
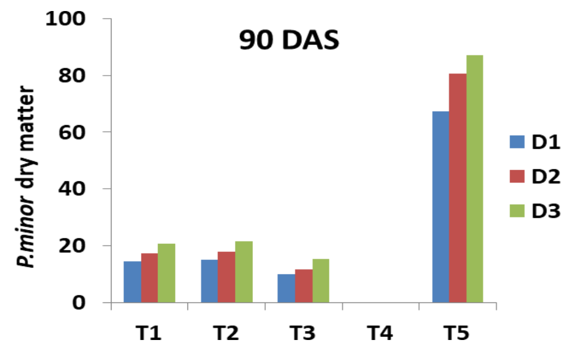
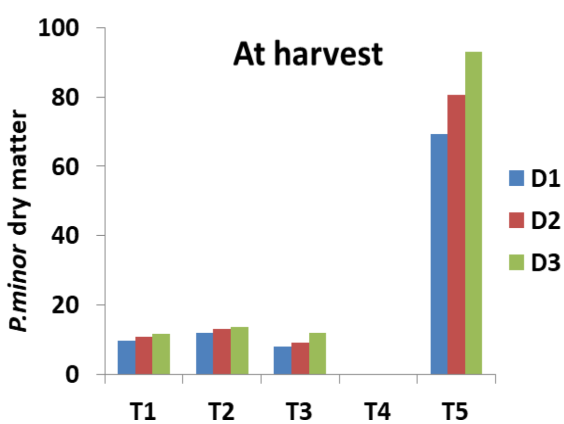
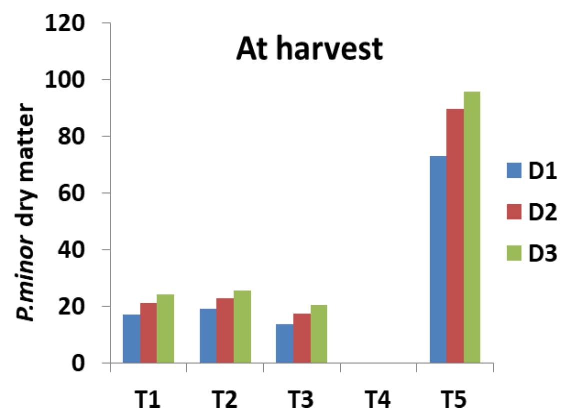
Table 4.1.5b. Interactions among different date of sowing and different weed control treatments on *P.minor* dry matter accumulation during 2018-19

Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
60 DAS						
1st November	6.14	6.62	4.01	0.00	37.14	10.78
20th November	5.74	7.68	3.90	0.00	44.13	12.29
10th December	7.46	7.13	4.94	0.00	60.17	15.94
Mean	6.44	7.15	4.28	0.00	47.15	
CD 5%	**1.68**					
90DAS						
1st November	9.83	10.36	7.05	0.00	59.45	17.34
20th November	10.62	11.61	7.93	0.00	68.76	19.78
10th December	12.30	12.13	10.54	0.00	79.65	22.93
Mean	10.92	11.37	8.51	0.00	69.29	
CD 5%	**3.62**					
At harvest						
1st November	9.66	11.90	7.98	0.00	69.39	19.79
20th November	10.83	13.19	9.17	0.00	80.68	22.77
10th December	11.77	13.55	11.82	0.00	93.03	26.03
Mean	10.75	12.88	9.66	0.00	81.03	
CD 5%	**3.27**					

Table 4.1.5c. Interactions among different date of sowing and different weed control treatments on *P.minor* dry matter accumulation during 2019-20

Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
60 DAS						
1st November	7.98	8.71	4.78	0.00	44.55	13.20
20th November	10.88	11.66	5.86	0.00	53.48	16.37
10th December	12.14	13.12	6.87	0.00	58.90	18.21
Mean	10.33	11.16	5.84	0.00	52.31	
CD 5%	**2.48**					
90DAS						
1st November	14.41	15.10	9.98	0.00	67.42	21.38
20th November	17.42	17.81	11.60	0.00	80.47	25.46
10th December	20.76	21.67	15.47	0.00	87.00	28.98
Mean	17.53	18.19	12.35	0.00	78.30	
CD 5%	**2.74**					
At harvest						
1st November	17.22	18.93	13.70	0.00	72.84	24.54
20th November	21.17	22.65	17.24	0.00	89.55	30.12
10th December	24.16	25.64	20.32	0.00	95.66	33.16
Mean	20.85	22.40	17.09	0.00	86.02	
CD 5%	**2.81**					

Fig .4.2 Interactive effect of date of sowing and different weed control treatment on *Phalaris minor* dry matter accumulation during year 2018-19 and 2019-20

2018-19	2019-20
	
	
	

D1: November 1st ,D2: November 20th , D3: December 10, T1: sulfosulfuron 25g/ha, T2: clodinafop 60g/ha fb metsulfuron 5g/ha, T3:sulfosulfuron 30g/ha, T4: weed free, T5: weedy check

4.1.6 Weed control efficiency

During 2018-19 and 2019-20 higher weed control efficiency was found in 1st November sown crop (75.5% and 71.5%, respectively) as compared to 20th November (71.7% and 65.1%,respectively) and 10th December sown crop (67.6% and 62.1%, respectively) [Table 4.1.6]. The highest efficiency was found in weed free treatment as compared to all weed control treatments followed by herbicides treatment sulfosulfuron + metsulfuron 30g /ha, Sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha. Similar trend was observed in both years 2018-19 and 2019-20 [Table 4.1.6].

Table 4.1.6 Effects of date of sowing and different weed control treatments on weed control efficiency (WCE) during 2018-19 and 2019-20 crop season

Dates of sowing	WCE % (2018-19)	WCE% (2019-20)
D1 (1 November)	75.50	71.55
D2 (20 November)	71.71	65.06
D3 (10 December)	67.62	62.11
Weed control treatment		
Sulfosulfuron 25g/ha	85.88	76.01
Clodinafop 60g/ha followed by metsulfuron 5g/ha	84.10	74.47
Sulfosulfuron + Metsulfuron 30g/ha	88.07	80.13
Weed free	100	100
Weedy check	-	-

4.1.7 Yield attribution

Effective tillers are directly related to crop yield. More are the effective tillers, higher is the crop grain yield. It was observed in the present study that numbers of effective tillers were significantly influenced by date of sowing. Sowing of crop at first date i.e. 1st November produced significantly higher tillers than that in crop sown on second and third date of sowing (Table 4.1.7a and Table 4.1.7b). Higher effective tillers were found in first sowing due to better growth of crop. Similar findings were observed in earlier reports (Hussain *et al*.,2012). Same trends were found in both years 2018-19 and 2019-20.

Different weed control treatments influence the effective tillers' number. It was observed that weeds free treatment recorded significantly higher number of effective tillers with respect to other weed control treatments. This is due to less competition for light, space and nutrient in weed free treatment. Among different herbicide treatments, sulfosulfuron + metsulfuron 30g/ha resulted in significantly higher number of tillers followed by sulfosulfuron 25g/ha and clodinafop 60g/ha followed by Metsulfuron 5g/ha. Weedy check observed lowest number of effective tillers. Interactions between sowing date and weed control treatments were observed to be statistically significant (Table 4.1.7c and 4.1.7d). Among different weed control treatments, first sowing date (1st November) produced significantly more no. of effective tillers in comparison with third date of sowing (20th December). Similar trends were observed in both years 2018-19 and 2019-20 crop seasons.

4.1.8 Spike length

The spike length influences the final crop yield, as number of grains usually increases with the spike length. The data on spike length are shown in Table 4.17a and 4.1.7b. From recorded data, it was observed that date of sowing significantly affected the spike length during both years, 2018-19 and 2019-20. Crop sown on 1st November recorded significantly higher spike length than 20th November and 20th December sown crops. Similar finding was reported earlier (Manoj Kumar *et al.,* 2019). Further, significantly lower spike length was recorded in weed check in both years as compared to other weed control treatments. Greater spike length was found in weed free treatment. Out of all three herbicidal treatments, sulfosulfuron + metsulfuron 30g/ha produced significantly longer spikes than weedy check but remained statistically at par with weed free treatment. The pattern of the results was similar during both 2018-19 and 2019-20 crop seasons.

4.1.9 No. of grains per spike

Data related to no. of grains/spike are illustrated in Table 4.1.7a and 4.1.7b. Total number of grains was significantly affected by dates of sowing. Crops sown on 1stNovember exhibited significantly maximum no. of grains per spike that were significantly higher than that of crops sown on 20th November and 20th December. Different weed control treatments significantly influenced total grains no. Higher grains no. per spike were recorded in weed free treatment, which was statistically at par with herbicide treatments sulfosulfuron + metsulfuron 30 g/ha but it was significantly higher than other weed control treatments. No significant interactions were found between dates of sowing and weed control treatments with respect to number of grains per panicle. Similar trend was observed during both years 2018-19 and 2019-20.

4.1.10 Test weight

Test weight is shown in Table 4.1.7a and 4.1.7b. The data revealed that 1000 grains weight was significantly affected by sowing times. The crop sown on 1st November resulted in significantly heavier grains than that in crop sown on 20th November and 10th December. Tahir *et al.* (2009) reported a decreasing grain weight with delaying in sowing time. The data showed that different weed control treatments significantly influenced the 1000 grain weight. Weed free treatment showed significantly heavier grain weight as compared to other weed control treatments except the treatment of sulfosulfuron + metsulfuron 30 g/ha. It remained statistically at par with herbicide treatment of sulfosulfuron + metsulfuron 30 g/ha. Weedy check showed significantly lower grain weight. It might be due to more weed competition for space, nutrient, moisture etc. Interactive effects between date of sowing and various weed control treatments were found to be non-significant. Similar result was observed during both years, 2018-19 and 2019-20.

Table 4.1.7a. Effects of date of sowing and different weed control treatment on effective tillers, spike length, number of panicles and 1000 grain weight in year 2018-19 and 2019-20

	Effective tillers/ m^2		Spike length in cm		Number of grains /spike		1000 grain weight (g)	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Dates of sowing								
D1 (1 November)	376.8	375.15	10.26	10.74	51.24	52.38	42.77	42.49
D2 (20 November)	372	368.08	9.63	9.77	50.84	51.93	42.23	42.04
D3 (10 December)	357.55	355.06	9.21	9.24	49.76	50.86	41.27	41.13
CD 5%	1.24	3.11	0.27	0.40	0.17	0.34	0.45	0.35
Weed control treatment								
Sulfosulfuron 25g/ha	373.46	364	9.73	10.05	51.01	52.11	42.34	42.20
Clodinafop 60g/ha followed by metsulfuron 5g/ha	367.33	370.26	9.46	9.64	50.32	51.39	41.80	41.63
Sulfosulfuron + Metsulfuron 30g/ha	378.93	376.26	10.72	11.074	52.20	53.38	43.43	43.04
Weed free	382.26	380.17	11.02	11.27	52.68	53.82	44.05	43.75
Weedy check	341.9	339.82	7.56	7.56	46.86	47.92	38.84	38.81
CD 5%	3.33	2.66	0.45	0.41	0.59	0.57	0.56	0.52
CD interaction	5.82	5.02	NS	NS	NS	NS	NS	NS

Table 4.1.7b. Interactions among different date of sowing and different weed control treatments on effective tillers during 2018-19 and 2019-20

Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
2018-19						
1st November	376.62	373.11	389.42	390.66	354.22	376.8
20th November	375.06	370.93	378.57	386.93	348.44	372
10th December	368.75	357.95	368.8	369.24	323.2	357.55
Mean	373.46	367.33	378.93	382.26	341.95	
CD 5%	5.822					
2019-20						
1st November	373.68	370.88	388.8	390.26	352.17	375.15
20th November	372.62	366	375.91	384.62	341.28	368.08
10th December	364.48	355.11	364.17	365.64	325.95	355.06
Mean	370.26	364	376.26	380.17	339.82	
CD 5%	5.02					

4.1.11 Grain yield

Data on grain yield has been shown in Table 4.1.8a and 4.1.8b. Crop yield depends upon its weed control potential as well as on growth and yield attributes. Date of sowing significantly affected the grain yield during both 2018-19 and 2019-20 crop seasons. Data revealed that maximum grain yield was resulted from 1st November sown crop which was significantly higher than that of 20th November and 10th December sown crop. Late sown resulted in lower grain yield because of lower germination %, lower number of effective tillers per m^2, smaller number of grains per spike and lower test weight due to less growing degree days to crop and high temperature causing stress during grain filling stage. The data obtained in the present investigation are well in agreement with earlier reports (Ishag, 1994; Spink *et a*l., 2000; Shahzad *et al.,* 2002; Aslam *et al*., 2003; Shah*et al*., 2006).

Weed control treatment also showed the significant effect on the grain yield. From all the weed control treatments, higher grain yield (49.55 q/ha and 47.12 q/ha in 2018-19 and 2019-20, respectively shown in Table 4.1.8a and 4.1.8b.) was found in weed free treatment and this treatment remained statistically alike with (47.86q/ha and 46.78q/ha) with herbicide treatment sulfosulfuron + metsulfuron 30 g/ha but showed significantly higher grain yield than other weed control treatments. Herbicide treatment of sulfosulfuron + metsulfuron 30 g/ha was found to exhibit significantly higher grain yield (43.03%, and 36.26.10%) than weedy check. Treatment of sulfosulfuron + metsulfuron 30g/ha led to poor weed growth which eventually increased the number of effective tillers, number of grains per spike and test weight. Similar results were also reported by Meena and Singh (2013) and Ali *et al.* (2016).Interaction effects were found to be significant between dates of sowing and weed control treatments. Interaction data for weed control and date of sowing treatments are shown in Table 4.2.8c. Herbicide and weed free treatment sulfosulfuron + metsulfuron 30 g/ha resulted in significantly higher grain yield at first date of sowing than other sowing dates. For weed free treatment, crop sown on 20th November and 10th December produced significantly less grain yield than application of sulfosulfuron + metsulfuron 30 g/ha at crop sown 1st November. This also holds good for 2019-20 crop season.

4.1.12 Straw yield

Straw is major component of total biological yield. Now-a-days it is also used for various purposes with economic importance. Present study revealed that dates of sowing exerted significant effects on the straw yield in both years 2018-19 and 2019-20 (Table 4.1.8a and 4.1.8b). Sowing of crop on 1st November yielded significantly more straw than that of crop sown on 20thNovember and 10th December. This is due to a greater number of tillers and higher crop dry matter accumulation. Similar findings were recorded by Donaldson *et al.* (2001). It further revealed, among various weed control treatments, weed free treatment yielded more straw, which was statistically at par with herbicide treatment of sulfosulfuron + metsulfuron 30 g/ha. Weed check treatment showed significantly lower straw yield when compared with all other treatments of weed control. The interaction was found to be significant between dates of sowing and different weed control treatments. Interaction data for date of sowing and weed control treatments, shown in Table 4.1.8d., confirmed that all weed control treatments were statistically significant and higher in 1st November sowing than 20th November and 10th December sowing. Similar results were observed during both years 2018-19 and 2019-20.

4.1.13 Harvest index (HI)

Data shown in Table 4.1.8a and 4.1.8b revealed a slightly increase in HI in the crop sown on 1st November in comparison to crop sown on 20th November and 10th December. HI decreased with delayed sowing time, which was due to decrease in grain yield and straw yield. Similar result was also given by Pathania *et al.*, (2018). Among different weed control treatments, weed free treatment showed higher HI followed by herbicide treatment sulfosulfuron + metsulfuron 30g/ha, sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha in a sequential order. Lower HI was recorded in weedy check (Un-weeded control). Results obtained in both 2018-19 and 2019-20 crop seasons showed similar trend.

Table 4.1.8a. Effects of date of sowing and different weed control treatments on grain yield, straw yield and harvest index (HI) during 2018-19 and 2019-20

	Grain q/ha		Straw q/ha		HI	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Dates of sowing						
D1 (1 November)	45.98	46.52	65.36	64.89	41.29	41.75
D2 (20 November)	42.4	41.37	60.87	60.24	41.05	40.71
D3 (10 December)	39.54	38.72	57.74	57.55	40.64	40.22
CD 5%	1.63	2.46	1.97	1.15		
Weed control treatment						
Sulfosulfuron 25g/ha	42.94	43.19	61.66	60.75	41.05	41.55
Clodinafop 60g/ha followed by metsulfuron 5g/ha	39.38	39.6	58.33	58.28	40.30	40.45
Sulfosulfuron + Metsulfuron 30g/ha	47.86	46.78	65	65.32	42.40	41.73
Weed free	49.55	47.12	66.9	65.63	42.55	41.79
Weedy check	33.46	34.33	54.75	54.47	37.93	38.65
CD 5%	3.09	2.72	2.11	1.77		
CD interaction	5.47	4.99	3.87	3.16		

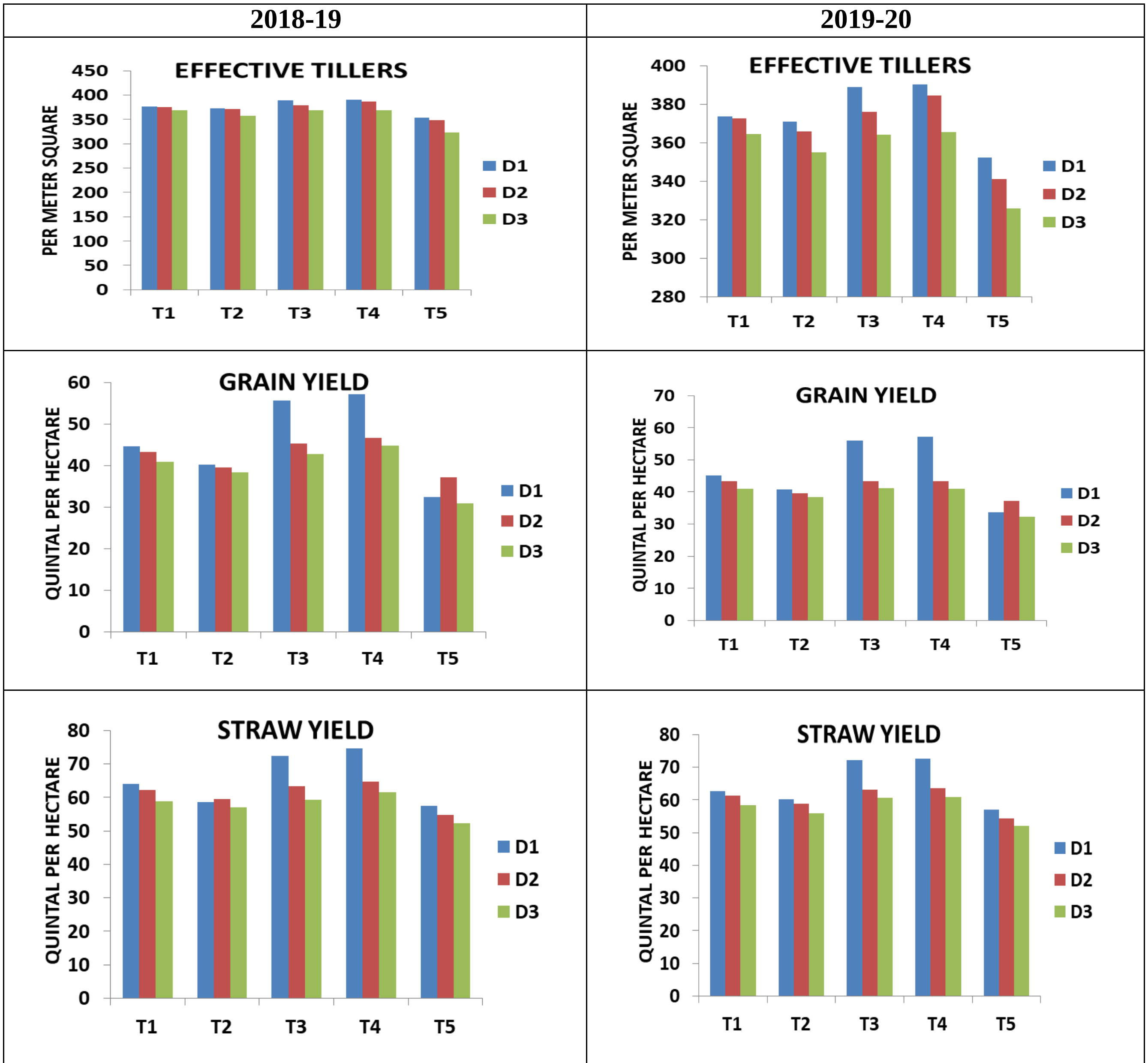
Table 4.1.8b. Interactions among different date of sowing and different weed control treatments on grain yield (q/ha) during 2018-19 and 2019-20

Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
2018-19						
1st November	44.63	40.20	55.60	57.10	32.36	45.98
20th November	43.33	39.60	45.26	46.70	37.13	42.40
10th December	40.86	38.36	42.73	44.86	30.90	39.54
Mean	42.94	39.38	47.86	49.55	33.46	
CD 5%	5.47					
2019-20						
1st November	45.06	40.80	55.96	57.20	33.60	46.52
20th November	43.43	39.70	43.28	43.26	37.20	41.37
10th December	41.08	38.31	41.10	40.91	32.20	38.72
Mean	43.19	39.60	46.78	47.12	34.33	
CD 5%	4.99					

Table 4.1.8c. Interactions among different date of sowing and different weed control treatments on straw yield (q/ha) during 2018-19 and 2019-20

2018-19						
Treatment	**Sulfosulfuron 25g/ha**	**Clodinafop 60g/ha followed by metsulfuron 5g/ha**	**Sulfosulfuron + Metsulfuron 30g/ha**	**Weed free**	**Weedy check**	**Mean**
1st November	64.03	58.50	72.36	74.53	57.40	65.36
20th November	62.11	59.46	63.43	64.70	54.66	60.87
10th December	58.83	57.03	59.20	61.46	52.20	57.74
Mean	61.66	58.33	65.00	66.90	54.75	
CD 5%	3.87					
2019-20						
1st November	62.63	60.23	72.06	72.48	57.03	64.89
20th November	61.33	58.80	63.16	63.60	54.33	60.24
10th December	58.30	55.83	60.73	60.83	52.06	57.55
Mean	60.75	58.28	65.32	65.63	54.47	
CD 5%	3.16					

Fig .4.3 Interactive effect of date of sowing and different weed control treatment on effective tillers, grain yield and straw yield during year 2018-19 and 2019-20.



D1: November 1st ,D2: November 20th , D3: December 10, T1: sulfosulfuron 25g/ha, T2: clodinafop 60g/ha fb metsulfuron 5g/ha, T3:sulfosulfuron 30g/ha, T4: weed free, T5: weedy check

Soil Analysis

Data on soil organic carbon, available nitrogen, available phosphorus and available potassium at harvest are shown in Table 4.1.9a and 4.1.9b

4.1.14 Organic carbon (OC)

OC is considered as back bone of soil fertility. The data revealed that dates of sowing exerted non-significant effect on the soil OC content in soil. OC content is majorly controlled by the presence of organic manures and humus in soil. However, it was also affected by fertilizers added and root biomass (Jat *et al.,* 2013). They found that OC content in soil remained statistically at par in early and late sown crop. In the present study, although different weed control treatments did not show any significant difference within themselves with respect to soil OC content but they exerted slightly positive impact as compared to weedy check treatment during both 2018-19 and 2019-20 crop seasons. Similar trend was reported earlier (Brar *et al.,* 2019).

4.1.15 Available Nitrogen

Available nitrogen content was non significantly influenced by the different dates of sowing. This might be due to similar dose of fertilizers applied to all treatments. The findings are agreed with Jat *et al.,* (2013).The different weed control treatments significantly influenced the post-harvest available nitrogen. Different weed control treatments recorded significantly higher available nitrogen content in comparison with weedy check treatment. This is due to higher uptake of nitrogen by weeds in un-weeded treatment. Higher uptake of nitrogen by weeds was also reported by Brar and Walia (2008). In the present study, results were found similar during 2018-19 and 2019-20. Interaction between the dates of sowing and different weed control measures on available nitrogen was found non-significant.

4.1.16 Available Phosphorus

Data showed that available phosphorus content in soil was not influenced by different dates of sowing. Similar results were reported by Prasad (2017). However, different weed control treatments were found to significantly influence the available phosphorus content in soil. Higher available phosphorus content in soil was available in weed control as compared to control treatment (un-weeded).Weed free treatment showed higher available phosphorus in soil sequentially followed by herbicide treatment sulfosulfuron + metsulfuron 30g/ha, sulfosulfuron 25g/ha and clodinafop 60 g/ha + metsulfuron 5g/ha; but all are statistically at par with each other. Mining of nutrient is more under un-weed treatment, leading to low phosphorus content in soil. Similar results were reported by Brar *et al.* (2019). Interactions between dates of sowing and weed control treatments on available phosphorus content in soil were found to be non-significant. Similar research trends were observed in both years, 2018-19 and 2019-20.

4.1.17 Available Potassium

The present study revealed that the date first sowing (1st November) recorded higher potassium content followed by sowing at second date (20th November) and third sowing date (10th December) but all were statistically at par with each other. Similar trends were evidenced by Prasad (2017). In that study of Prasad (2017), an apparent improvement in available potassium content in soil was reported with early sowing as compared to late sowing but statistically they remained non-significant with each other. In the present study, the trends remained same in both 2018-19 and 2019-20 crop seasons. However, available potassium was significantly influenced by different weed control treatments. Weed free treatment were found to contain higher available potassium in soil followed by herbicide treatment sulfosulfuron + metsulfuron 30g/ha, sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha. Weed check showed lowest available potassium content in soil. This might be due to more uptake of potassium by weeds. Similar results were reported by Brar *et al.* (2019).Interactive effects between dates of sowing and weed control treatments were found non-significant. Similar research trends were observed in both 2018-19 and 2019-20 crop seasons.

Table 4.1.9. Effects of date of sowing and different weed control treatments on organic carbon (OC), available nitrogen (N), available phosphorus (P) and available potassium (K) in soil at harvest during 2018-19 and 2019-20

	OC (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Dates of sowing								
D1 (1 November)	0.44	0.45	180.20	181.20	15.30	15.56	154.40	157.93
D2 (20 November)	0.43	0.43	179.73	180.60	14.68	15.20	153.33	157.06
D3 (10 December)	0.43	0.43	179.00	179.26	14.54	15.26	152.20	156.66
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS
Herbicide treatment								
Sulfosulfuron 25g/ha	0.43	0.44	180.66	180.88	15.00	15.46	153.33	157.44
Clodinafop 60g/ha followed by metsulfuron 5g/ha	0.43	0.43	179.66	180.55	14.83	15.43	150.77	154.22
Sulfosulfuron + Metsulfuron 30g/ha	0.44	0.44	181.33	182.11	15.18	15.56	157.00	160.66
Weed free	0.43	0.45	181.44	182.33	15.28	15.84	158.77	162.66
Weedy check	0.42	0.42	175.11	175.88	13.90	14.40	146.66	151.11
CD 5%	NS	NS	2.15	3.44	0.79	0.51	1.67	0.85
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

Experiment: 2

Effect of sowing methods and weed control treatments on growth and development of plants and weeds

4.2.1 Plant height

Plant height data was significantly influenced by different weed control methods and various sowing methods, recorded periodically during 2018-19 and 2019-20, and has been prescribed in Table 4.2.1a and 4.2.1b. The difference in plant height due to different sowing methods was non-significant when recorded at 30 DAS. The plant height recorded at 60 DAS, was found to be significantly higher in bi-directional sowing as compared to the crop sown at spacing of 15 cm, 17.5 cm and 22.5 cm as unidirectional. However, the plant height of crop sown at spacing of 15 cm and 17.5 cm was found to be statistically at par but significantly more than the crop sown at spacing of 22.5 cm. The data at 90 DAS and at harvest showed no significant difference. Research findings remained same during both 2018-19 and 2019-20 crop seasons.

Regarding weed control treatments, treatment effects were found non significant at 30 DAS, as weed control treatments were applied on 30 DAS. However, all weed control treatments recorded significantly higher plant height as compared to unweeded (control) treatment at 60, 90 DAS and at harvest. The data confirms the findings reported by Nanher and Raghuvir (2015). Among herbicidal treatment, significantly higher plant height was recorded at all periodic interval (except 30DAS) with the application of sulfosulfuron + metsulfuron 30g/ha as compared to the application of sulfosulfuron 25g/ha and clodinafop 60g/ha followed by metsulfuron 5g/ha. Least plant height was recorded in weedy check due to the more density of weeds. Increased plant height might be due to the better utilization of resources such as nutrients, light and moisture by the crop plants as well as the weed free environment caused by different herbicidal treatments and hand weeding. The interactive effects of sowing time and different weed control treatments were non-significant. Similar findings were obtained during both crop seasons, 2018-2019 and 2019-2020.

Table 4.2.1. Effects of various sowing methods and weed control treatments on plant height during 2018-19 and 2019-20

	30 DAS		60 DAS		90 DAS		At harvest	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Methods of sowing								
Row spacing 15cm	26.68	26.61	58.22	57.87	91.50	92.22	98.17	97.72
Row spacing 17.5cm	26.46	26.39	57.82	57.67	91.33	91.68	98.41	97.62
Row spacing 22.5cm	26.53	26.46	56.72	55.52	91.64	91.86	97.41	97.70
Bi directional sowing	26.31	26.24	59.43	59.28	92.30	92.65	98.84	98.34
CD 5%	NS	NS	0.66	0.766	NS	NS	NS	NS
Weed control treatment								
Sulfosulfuron 25g/ha	26.42	26.58	58.78	58.29	91.40	91.79	99.22	98.57
Clodinafop 60g/ha followed by metsulfuron 5g/ha	26.65	26.35	58.31	58.21	90.60	91.40	97.91	97.13
Sulfosulfuron + Metsulfuron 30g/ha	26.40	26.33	60.38	59.74	94.43	94.75	100.35	100.43
Weed free	26.42	26.35	61.33	60.51	95.03	95.57	100.47	100.47
Weedy check	26.58	26.51	51.46	51.17	87.00	87.01	93.08	92.63
CD 5%	NS	NS	1.15	0.88	1.62	1.98	1.222	1.154
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

4.2.2 Tillers per meter square

Number of tillers is considered as a crucial growth parameter which influences the final yield. The number of tillers, recorded at different periodic intervals of 30, 60, 90 DAS and at harvest, is shown in Table 4.2.2a and 4.2.2b. Number of tillers was significantly affected at 60, 90 DAS and at harvest stage with respect to sowing methods. Maximum numbers of tillers per meter square were found in bi-directional sowing. Bi-directional sowing evenly distributed the seeds with definite spatial pattern which encourages proper utilization of spaces than the conventional methods. The results conform the findings of Hussain *et al*. (2017). Followed by bi-directional sowing; crop sown at spacing of 15 cm and 17.5 cm also exhibited significant more no. of tillers but statistically at par with each other. Least number of tillers was recorded in crop sown with spacing of 22.5 cm.

Various weed control treatments provided significant positive influence on the number of tillers. Weed free treatment recorded maximum number of tillers followed by herbicide treatment of sulfosulfuron + metsulfuron 30g/ha which produced statistically significant higher number of tillers than other herbicide treatments. Weed check recorded least number of tillers. This might be due to less removal of nutrients by weeds and crops were exposed to favorable conditions and more availability of nutrient, moisture, light etc., that were congenial for crop growth (Punia *et al*., 2017).

Table 4.2.2. Effects of various sowing methods and weed control treatments on number of tillers during 2018-19 and 2019-20

Number of tillers per meter square during 2018-19and 2019-20								
	30 DAS		**60 DAS**		**90 DAS**		**At harvest**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Methods of sowing								
Row spacing 15cm	238.06	241.09	364.35	365.86	390.15	394.35	385.40	385.80
Row spacing 17.5cm	239.37	238.03	363.52	365.19	389.23	393.51	383.40	384.06
Row spacing 22.5cm	238.98	237.97	351.32	356.87	380.89	381.23	377.33	378.13
Bi directional sowing	238.25	237.10	371.06	372.61	396.64	400.97	391.66	392.33
CD 5%	NS	NS	3.11	2.86	2.53	3.09	5.34	4.92
Weed control treatment								
Sulfosulfuron 25g/ha	240.07	239.30	362.97	365.92	389.26	392.73	382.00	385.33
Clodinafop 60g/ha followed by metsulfuron 5g/ha	236.10	237.00	361.85	362.14	388.29	391.85	382.90	383.16
Sulfosulfuron + Metsulfuron 30g/ha	239.00	239.90	368.19	371.39	394.72	398.19	389.33	390.25
Weed free	237.40	236.63	373.29	376.48	399.82	403.29	393.83	394.41
Weedy check	240.75	239.91	346.53	349.72	373.06	376.53	371.16	372.25
CD 5%	NS	NS	2.77	3.65	2.59	2.74	3.97	3.58
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

4.2.3 Dry matter of plants

Crop DM is important pre-harvest growth parameter which has great influence on final crop yield. Crop dry matter recorded at periodic intervals is shown in Table 4.2.3a and 4.2.3b. Different sowing methods exhibited significant effect on dry matter accumulation. At 60 DAS, 90 DAS and at harvest, dry matter accumulation was significantly higher in bi-directional sowing than unidirectional sowing at different spacings. Dry matter accumulations in crops, sown at spacing of

17.5 cm and 15 cm, were statistically at par with each other but significantly higher than that of the crops sown at 22.5 cm. Similar results were found in the second year.

The dry matter accumulation in crop plants was significantly affected by different weed control treatments. Weed free treatment produced significantly higher dry matter as compared to other treatments. At 60 DAS, dry matter accumulation in weed free treatment and herbicide treatments of sulfosulfuron + metsulfuron 30g/ha was statistically at par with each other but significantly higher than other treatments. At 90 DAS and at harvest, weed free treatments were found to be significantly better than other treatments and it was followed by sulfosulfuron + metsulfuron 30g/ha. Least dry matter accumulation was recorded in weedy check. Similar explanation is applicable for dry matter accumulation also as it has was stated in the case of plant height and number of panicles. Similar observation was reported by Punia *et al*., (2011). There is no significant interaction between sowing methods and weed control treatments with respect to dry matter accumulation. Similar results were observed during both 2018-2019 and 2019-2020 crop seasons.

Table 4.2.3. Effects of various sowing methods and weed control treatments on dry matter accumulation during 2018-19 and 2019-20

Dry matter plant (g/m^2) during 2018-19and 2019-20								
	30 DAS		**60 DAS**		**90 DAS**		**At harvest**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Methods of sowing								
Row spacing 15cm	21.19	21.12	260.55	260.14	590.15	593.70	1054.57	1065.87
Row spacing 17.5cm	20.51	21.81	258.91	261.58	589.23	594.20	1054.75	1065.78
Row spacing 22.5cm	20.00	20.51	256.50	257.58	576.89	581.36	1039.18	1050.33
Bi directional sowing	20.56	21.18	269.85	270.99	596.64	601.11	1059.59	1070.92
CD 5%	NS	NS	1.79	1.670	2.73	2.694	5.01	4.967
Weed control treatment								
Sulfosulfuron 25g/ha	20.94	21.55	263.17	264.29	588.26	592.73	1052.24	1063.47
Clodinafop 60g/ha followed by metsulfuron 5g/ha	20.88	21.44	261.51	262.63	588.29	592.76	1052.08	1063.07
Sulfosulfuron + Metsulfuron 30g/ha	20.3	20.66	264.81	265.78	593.72	598.19	1057.67	1068.82
Weed free	20.43	20.97	265.64	266.79	598.82	603.29	1061.28	1072.62
Weedy check	20.55	21.17	252.12	253.38	572.06	576.53	1036.85	1048.14
CD 5%	NS	NS	1.42	1.37	2.59	2.60	3.16	2.98
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

4.2.4 *Phalaris minor* count

Phalaris minor counts recorded at 30, 60, 90 DAS and at harvest are shown in Table 4.2.4a and 4.2.4b. Different sowing methods were found significantly affecting the Phalaris density. At 60, 90 DAS and at harvest bi-directional sowing decreased population of *P. minor* significantly as compared to single directional sowing at different spacings. This might be due to change in planting pattern that caused smothering effect and it helped to reduce the number of weeds. More crop smothering and weed suppression in bi-directional sowing were due to the fact that it offered spatial uniformity pattern to crop, which is very effective for crops to smother weeds at earlier stages (Kristensen *et al*., 2008). Pandey and Kumar (2005) also asserted that cross sowing significantly helped in reduction of weed counts. Followed by bi-directional sowing, crops sown at spacing of 15cm resulted in more suppression of *P. minor* population than crops sown at spacing of 17.5cm and 22.5 cm. Maximum numbers of *P. minor* weeds were recorded in crops sown at broader spacing of 22.5cm. Fahad *et al*. (2015) also reported lesser weed growth in narrow row spacing as compared to wider rows for wheat crop.

As the herbicides was applied at 30 DAS, weed density remained statistically same in all weed control treatments. Weedy check showed significantly higher *P. minor* population as compared to other weed control treatments. Weed population was zero in weed free treatment**.** From the different treatments of herbicides, application of post-emergence sulfosulfuron + metsulfuron 30g/ha showed significantly a smaller number of *P. minor* than the applications of sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha.

Table 4.2.4a. Effects of sowing methods and different weed control treatments on *P. minor* count during 2018-19 and 2019-20

P. minor count per meter square during 2018-19and 2019-20								
	30 DAS		60 DAS		90 DAS		At harvest	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Methods of sowing								
Row spacing 15cm	79.81	81.89	28.04	29.43	28.24	29.13	30.08	30.31
Row spacing 17.5cm	81.01	83.08	28.90	31.78	32.38	30.64	31.77	31.65
Row spacing 22.5cm	81.92	84.00	30.24	34.51	34.06	32.13	33.55	34.10
Bi directional sowing	77.23	79.31	27.18	27.18	26.16	26.84	26.88	27.55
CD 5%	NS	NS	0.842	1.89	1.41	1.222	1.48	0.952
Weed control treatment								
Sulfosulfuron 25g/ha	80.42	82.50	11.50	14.17	17.06	15.77	18.98	18.6
Clodinafop 60g/ha followed by metsulfuron 5g/ha	79.45	81.52	15.01	17.68	19.51	17.66	22.67	19.59
Sulfosulfuron + Metsulfuron 30g/ha	80.14	82.22	9.04	11.71	15.35	14.46	16.30	16.08
Weed free	79.54	81.62	0.0	0.0	0.0	0.0	0.0	0.0
Weedy check	80.41	82.49	107.40	110.06	99.14	100.55	94.91	100.16
CD 5%	NS	NS	0.84	0.94	1.40	1.306	1.66	0.76
CD interaction	NS	NS	1.74	2.08	2.92	2.701	3.43	1.608

The interactive effects were found to be significant in between method of sowings and weed control treatments during 2018-19 (Table 4.2.4c) Herbicides sulfosulfuron + metsulfuron 30g/ha showed a smaller number of weeds at all date of sowing as compared to the treatments of sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha.

Interaction effect on *P. minor* count at 60 DAS indicated a similar application effect of sulfosulfuron and metsulfuron in all adopted sowing methods. In bi-directional sown crop, *P.minor* count was significantly less in sulfosulfuron + metsulfuron 30g/ha as compared to sulfosulfuron 25g/ha and clodinafop 60g/ha followed by metsulfuron 5g/ha.

Clodinafop 60g/ha followed by metsulfuron 5g/ha recorded significantly higher *P. minor* count in row to row spacing of 15 cm and 22.5 cm at 90 DAS as compared to the application of sulfosulfuron + metsulfuron 30g/ha . The number of panicles of *P.minor* at the time of harvest were found to be significantly less in bi-directional sown crop treated with sulfosulfuron + metsulfuron 30g/ha as compared to the application of sulfosulfuron 25g/ha and clodinafop 60g/ha in all sowing methods. Interaction effects between different weed control and sowing methods treatments recorded at 60, 90 DAS and at harvest for *P. minor* count per square meter were found to be significant during 2019-20 (Table 4.2.4d). Bi-directional sowing in sulfosulfuron 25 g/ha treated plots was statistically at par with the crop sown at 15cm and 17.5cm under sulfosulfuron + metsulfuron 30g/ha treatment. Further, in bi-directional sowing; sulfosulfuron + metsulfuron 30g/ha recorded significantly less *P. minor* count as compared to other herbicidal treatments applied in all sowing methods when observations were recorded at 90 DAS. At harvest, bi-directional sowing with post emergence application of sulfosulfuron 25g/ha was found statistically at par with row 15 cm and 17.5cm where crops were treated with sulfosulfuron + metsulfuron 30g/ha.

4.2.4 b. Interaction between sowing methods and weed control treatments on *Phalaris minor* count during 2018-19

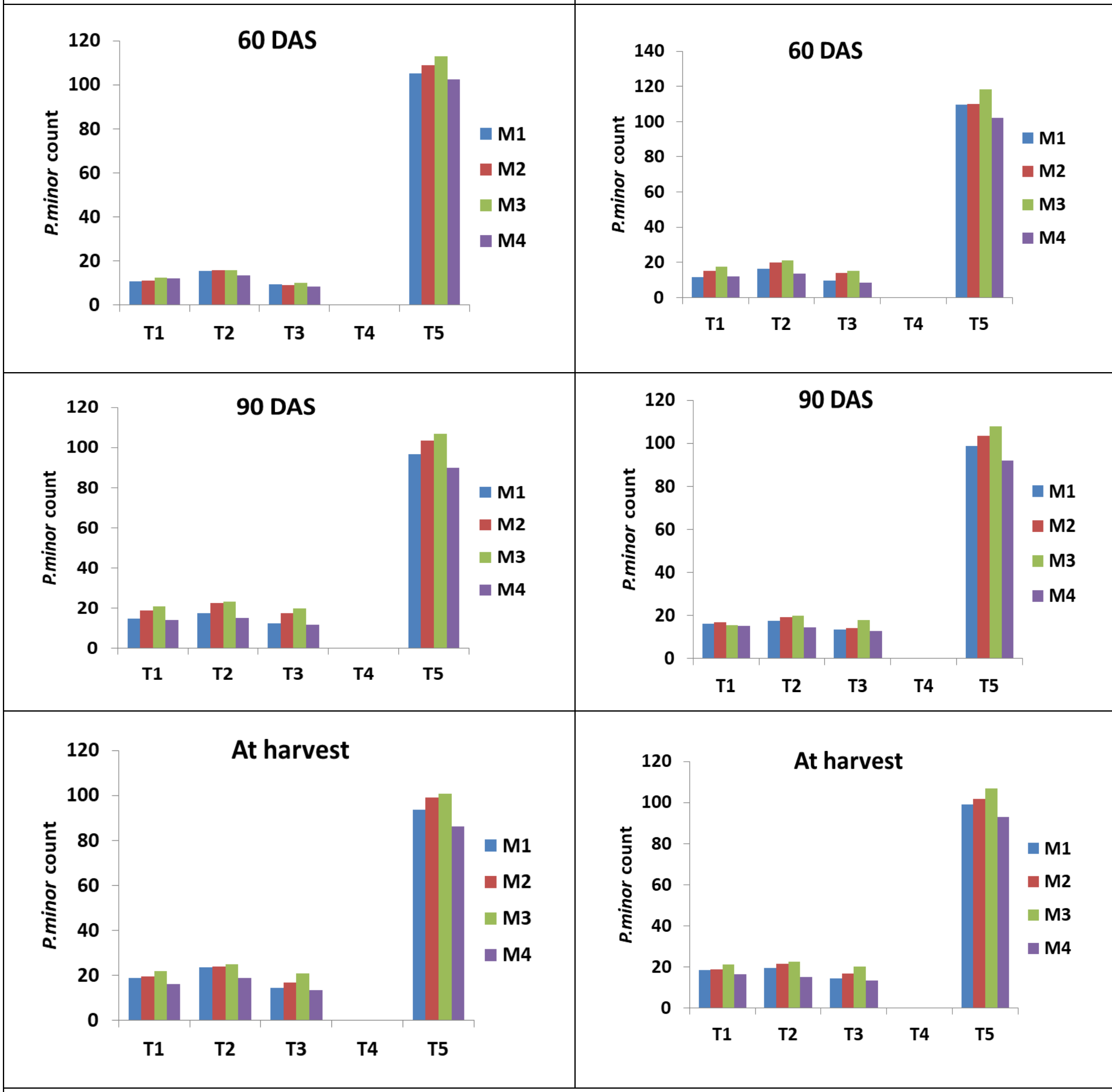
Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
60 DAS						
Row Spacing 15cm	10.61	15.240	9.15	0.00	105.23	28.04
Row Spacing 17.5cm	11.12	15.543	8.85	0.00	109.00	28.90
Row Spacing 22.5cm	12.38	15.867	9.94	0.00	113.03	30.24
Bi-directional sowing	11.91	13.407	8.25	0.00	102.33	27.18
Mean	11.50	15.014	9.04	0.00	107.40	
CD 5%	1.74					
90DAS						
Row Spacing 15cm	14.66	17.45	12.38	0.00	96.70	28.24
Row Spacing 17.5cm	18.73	22.46	17.39	0.00	103.33	32.38
Row Spacing 22.5cm	20.68	23.03	19.90	0.00	106.70	34.06
Bi-directional sowing	14.16	15.11	11.72	0.00	89.83	26.16
Mean	17.06	19.51	15.35	0.00	99.14	
CD 5%	2.92					
At harvest						
Row Spacing 15cm	18.76	23.59	14.40	0.00	93.66	30.08
Row Spacing 17.5cm	19.39	23.70	16.80	0.00	99.00	31.77
Row Spacing 22.5cm	21.70	24.73	20.66	0.00	100.66	33.55
Bi-directional sowing	16.06	18.66	13.33	0.00	86.33	26.88
Mean	18.98	22.67	16.30	0.00	94.91	
CD 5%	3.43					

Table 4.2.4c. Interaction between sowing methods and weed control treatments on *Phalaris minor* count during 2019-20

Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
60 DAS						
Row Spacing 15cm	11.78	16.21	9.51	0.00	109.66	29.43
Row Spacing 17.5cm	15.27	19.90	13.81	0.00	109.90	31.78
Row Spacing 22.5cm	17.71	21.20	15.27	0.00	118.36	34.51
Bi-directional sowing	11.91	13.40	8.25	0.00	102.33	27.18
Mean	14.17	17.68	11.71	0.00	110.06	
CD 5%	2.08					
90DAS						
Row Spacing 15cm	16.20	17.38	13.30	0.00	98.76	29.13
Row Spacing 17.5cm	16.59	19.24	14.06	0.00	103.33	30.64
Row Spacing 22.5cm	15.20	19.78	17.66	0.00	108.00	32.13
Bi-directional sowing	15.09	14.24	12.80	0.00	92.10	26.84
Mean	15.77	17.66	14.46	0.00	100.55	
CD 5%	2.70					
At harvest						
Row Spacing 15cm	18.58	19.56	14.43	0.00	99.00	30.31
Row Spacing 17.5cm	18.66	21.36	16.56	0.00	101.66	31.65
Row Spacing 22.5cm	20.96	22.53	20.00	0.00	107.00	34.10
Bi-directional sowing	16.52	14.90	13.33	0.00	93.00	27.55
Mean	18.68	19.59	16.08	0.00	100.16	
CD 5%	1.60					

Fig .4.4 Interactive effect of sowing methods and different weed control treatment on *Phalaris minor* count during year 2018-19 and 2019-20.

2018-19	2019-20



M1: Row Spacing 15cm,M2: Row Spacing 17.5cm, M3:Row Spacing 22.5cm, M4: Bi-directional sowing T1: sulfosulfuron 25g/ha, T2: clodinafob 60g/ha fb metsulfuron 5g/ha, T3:sulfosulfuron 30g/ha, T4: weed free, T5: weedy check

4.2.5 Dry matter accumulation

Periodical data on dry matter accumulation in *Phalaris minor* were recorded at 30, 60, 90 DAS and at harvest (Table 4.2.5a and 4.2.5b).It has been observed that sowing methods significantly influenced the *Phalaris minor* dry matte accumulation. In bi-directional sowing, dry matter accumulation at 60, 90 DAS and at harvest was found less as compared to single directional at different spacing. Pandey and Kumar (2005) also reported similar findings. The results obtained in bi-directional sown crop followed an increasing order by the crops sown at spacing 15cm, 17.5cm and 22.5cm. Maximum dry matter accumulation in *P.minor* population was recorded in case of wheat crop sown at spacing 22.5cm.

Various weed control treatments significantly influenced the weed dry matter accumulation. Weed control treatments were non- significant at 30 days after sowing, as the herbicides were applied at 30 DAS. *P.minor* dry matter was found to be zero in weed free treatment**.** From different herbicides treatments, sulfosulfuron + metsulfuron 30g/ha led to significantly less dry matter accumulation than that of sulfosulfuron 25g/ha and clodinafop 60g/ha + metsulfuron 5g/ha.

Table 4.2.5a. Effect of sowing methods and different weed control treatments on *Phalaris minor* dry matter production during 2018-19 and 2019-20

***P. minor* dry matter accumulation (g/m^2) during 2018-19and 2019-20**								
	30 DAS		**60 DAS**		**90 DAS**		**At harvest**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Methods of sowing								
Row spacing 15cm	13.30	13.64	15.47	15.71	24.99	26.12	29.79	31.09
Row spacing 17.5cm	13.50	13.85	18.49	16.18	26.31	27.48	31.90	32.51
Row spacing 22.5cm	13.64	13.99	20.29	16.93	27.80	28.80	33.91	35.01
Bi directional sowing	12.86	13.21	14.30	15.22	23.15	24.06	26.96	28.29
CD 5%	NS	NS	1.03	0.46	1.133	1.09	1.507	1.05
Weed control treatment								
Sulfosulfuron 25g/ha	13.40	13.75	8.14	6.44	13.75	14.13	18.65	19.17
Clodinafop 60g/ha followed by metsulfuron 5g/ha	13.24	13.58	10.10	8.40	14.75	15.83	19.09	20.13
Sulfosulfuron + Metsulfuron 30g/ha	13.35	13.70	6.84	5.06	12.22	12.96	15.56	16.52
Weed free	13.25	13.60	0.00	0.00	0.00	0.00	0.00	0.00
Weedy check	13.38	13.73	60.69	60.15	87.09	90.15	99.90	102.82
CD 5%	NS	NS	0.55	0.70	1.55	1.18	1.96	2.07
CD interaction	NS	NS	1.21	1.43	3.18	2.43	4.02	4.20

The interaction between different crop sowing methods and weed control treatments during 2018-19 was found to be significant (Table 4.2.5c). Herbicides sulfosulfuron + metsulfuron 30 g/ha reduced the dry matter weight of *P.minor* significantly at all dates of sowing as compared to herbicide clodinafop 60 g/ha + metsulfuron 5 g/ha and sulfosulfuron 25 g/ha. This is due to the fact of reduced population of the weeds due to herbicidal treatments.

However, all herbicidal treatments recorded a significant reduction in weed dry matter. The results conform earlier findings (Brar and Walia, 2007; Singh *et al.,* 2010; Meena and Singh., 2013).

At 60 DAS, application of sulfosulfuron + metsulfuron in bi-directional sowing and crop sown at 15cm row to row spacing resulted in significant reduction in *P. minor* dry weight as compared to clodinafop 60 g/ha followed by metsulfuron treatment in all sowing methods. Bi-directional sowing treated with sulfosulfuron + metsulfuron 30 g/ha recorded significantly lower dry matter accumulation by *P. minor* at 90 DAS as compared to crop sown at spacing of 22.5 cm treated with sulfosulfuron 25 g/ha and clodinafop 60 g/ha followed by metsulfuron 5 g/ha.

From interaction data for *P. minor* dry matter accumulation, significantly less dry matter was observed at the time of harvest in cross sowing with sulfosulfuron + metsulfuron 30 g/ha as compared to application of other herbicidal treatments in all row to row spacing techniques.

Dry matter, recorded at 60 DAS during 2019-20 (Table 4.2.5d) in bi-directional sown crop, indicated a steady decrease in dry matter of *P. minor* when sulfosulfuron + metsulfuron 30 g/ha was applied for weed control measurement and the reduction was found significantly higher than that of clodinafop 60 g/ha followed by metsulfuron. Similar trends were observed in all adopted sowing methods. At 90 DAS, dry matter in *P. minor* was found to be significantly less in sulfosulfuron + metsulfuron 30 g/ha treatment in cross sowing (bi-directional) as compared to application of clodinafop 60 g/ha followed by metsulfuron 5 g/ha in all other sowing methods. Similar trends was also observed at the time of harvest.

4.2.5b. Interaction between sowing methods and weed control treatments on dry matter of *Phalaris minor* during 2018-19

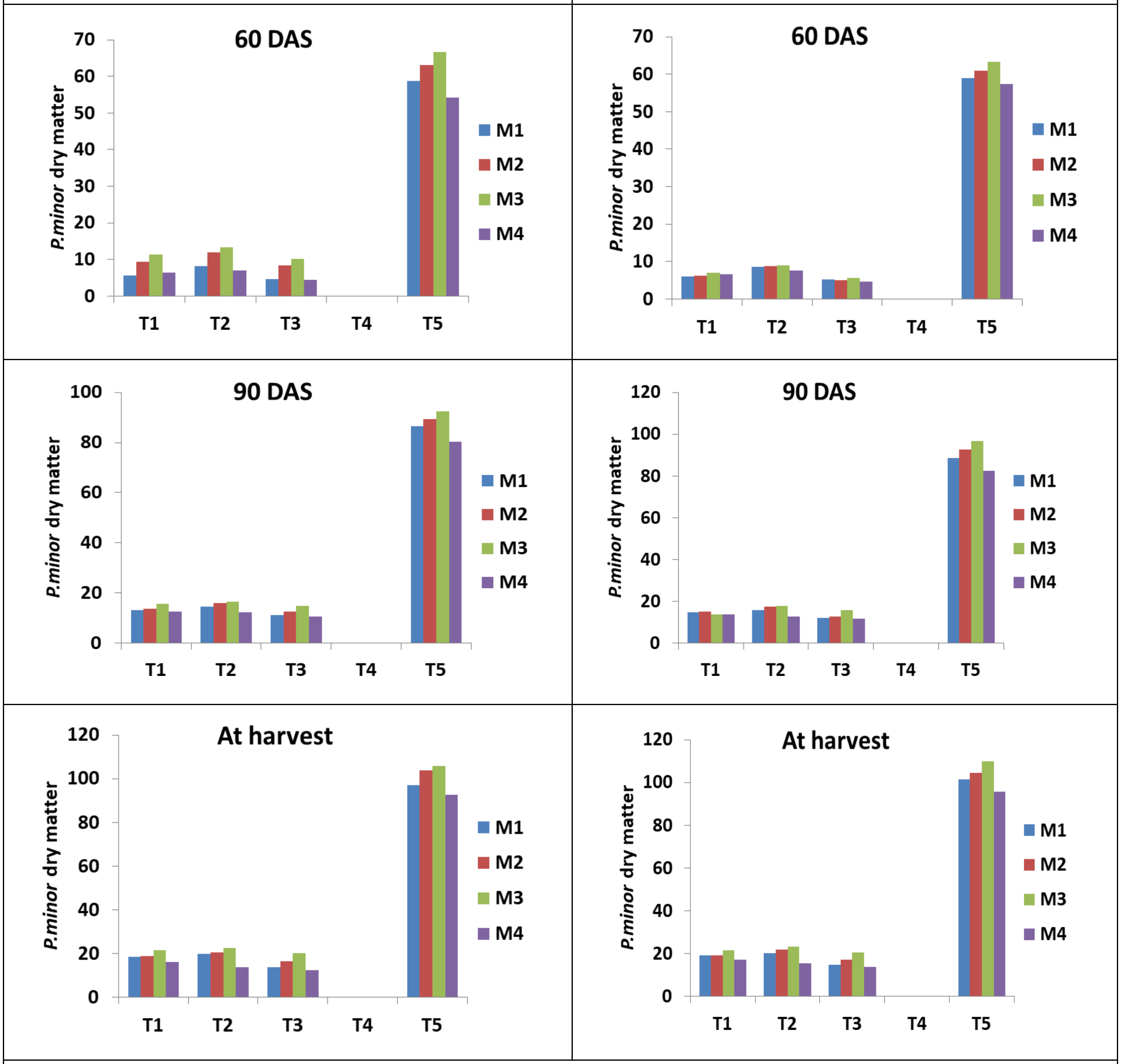
60 DAS						
Treatment	**Sulfosulfuron 25g/ha**	**Clodinafop 60g/ha followed by metsulfuron 5g/ha**	**Sulfosulfuron + Metsulfuron 30g/ha**	**Weed free**	**Weedy check**	**Mean**
Row Spacing 15cm	5.64	8.23	4.64	0.00	58.83	15.47
Row Spacing 17.5cm	9.26	11.83	8.32	0.00	63.05	18.49
Row Spacing 22.5cm	11.36	13.39	10.06	0.00	66.62	20.29
Bi-directional sowing	6.30	6.96	4.35	0.00	54.27	14.38
Mean	8.14	10.10	6.84	0.00	60.69	
CD 5%	1.21					
90DAS						
Row Spacing 15cm	13.11	14.39	11.06	0.00	86.39	24.99
Row Spacing 17.5cm	13.76	15.90	12.56	0.00	89.35	26.31
Row Spacing 22.5cm	15.49	16.40	14.80	0.00	92.34	27.80
Bi-directional sowing	12.66	12.32	10.47	0.00	80.29	23.15
Mean	13.75	14.75	12.22	0.00	87.09	
CD 5%	3.18					
At harvest						
Row Spacing 15cm	18.41	19.87	13.53	0.00	97.16	29.79
Row Spacing 17.5cm	18.79	20.60	16.35	0.00	103.76	31.90
Row Spacing 22.5cm	21.30	22.35	19.97	0.00	105.93	33.91
Bi-directional sowing	16.11	13.53	12.39	0.00	92.76	26.96
Mean	18.65	19.09	15.56	0.00	99.90	
CD 5%	4.02					

4.2.5 c. Interaction between sowing methods and weed control treatments on dry matter of *Phalaris minor* during 2019-20

60 DAS						
Treatment	**Sulfosulfuron 25g/ha**	**Clodinafop 60g/ha followed by metsulfuron 5g/ha**	**Sulfosulfuron + Metsulfuron 30g/ha**	**Weed free**	**Weedy check**	**Mean**
Row Spacing 15cm	5.94	8.53	5.12	0.00	58.95	15.71
Row Spacing 17.5cm	6.23	8.70	4.95	0.00	61.03	16.18
Row Spacing 22.5cm	6.93	8.88	5.56	0.00	63.30	16.93
Bi-directional sowing	6.66	7.50	4.62	0.00	57.31	15.22
Mean	6.44	8.40	5.06	0.00	60.15	
CD 5%	1.43					
90DAS						
Row Spacing 15cm	14.52	15.58	11.93	0.00	88.55	26.12
Row Spacing 17.5cm	14.87	17.25	12.61	0.00	92.66	27.48
Row Spacing 22.5cm	13.58	17.74	15.84	0.00	96.83	28.80
Bi-directional sowing	13.53	12.77	11.47	0.00	82.56	24.06
Mean	14.13	15.83	12.96	0.00	90.15	
CD 5%	2.43					
At harvest						
Row Spacing 15cm	19.08	20.09	14.82	0.00	101.49	31.09
Row Spacing 17.5cm	19.14	21.96	17.03	0.00	104.42	32.51
Row Spacing 22.5cm	21.50	23.14	20.55	0.00	109.85	35.01
Bi-directional sowing	16.96	15.31	13.69	0.00	95.51	28.29
Mean	19.17	20.13	16.52	0.00	102.82	
CD 5%	4.20					

Fig .4.5 Interactive effect of sowing methods and different weed control treatment on *Phalaris minor* dry matter accumulation during year 2018-19 and 2019-20.

2018-19	2019-20



M1: Row Spacing 15cm,M2: Row Spacing 17.5cm, M3: Row Spacing 22.5cm, M4: Bi-directional sowing T1: sulfosulfuron 25g/ha, T2: clodinafop 60g/ha fb metsulfuron 5g/ha, T3:sulfosulfuron 30g/ha, T4: weed free, T5: weedy check

4.2.6 Weed control efficiency

During 2018-19 and 2019-20, higher weed control efficiency (73.01% and 72.48%) was obtained in bi- directional sowing as compared to crops sown at spacing of 15 cm, 17.5 cm and 22.5 cm in single direction (Table 4.2.6). Least weed control efficiency (66.05 and 65.95) was found in crop sown at spacing of 22.5cm. Among different weed control treatments, weed free treatment recorded higher weed control efficiency which followed by herbicides treatment sulfosulfuron + metsulfuron 30 g/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5g/ha. Similar research trends were observed during both 2018-19 and 2019-20 crop seasons.

Table 4.2.6 Effect of sowing methods and different weed control treatment on weed control efficiency (WCE) in year 2018-19 and 2019-20

Methods of sowing	WCE % (2018-19)	WCE% (2019-20)
Row spacing 15cm	70.18	69.76
Row spacing 17.5cm	68.06	68.38
Row spacing 22.5cm	66.05	65.95
Bi directional sowing	73.01	72.48
Weed control treatment		
Sulfosulfuron 25g/ha	81.33	81.35
Clodinafop 60g/ha followed by metsulfuron 5g/ha	80.89	80.42
Sulfosulfuron + Metsulfuron 30g/ha	84.42	83.93
Weed free	100	100
Weedy check	-	-

4.2.7 Effective tillers per square meter

Effective tillers directly influence the final crop yield. With increasing effective tillers, more will be the crop yield. Present investigation revealed that sowing methods significantly influenced the number of effective tillers (Table 4.2.7a and 4.2.7b). Bi-directional sowing recorded significantly more number of tillers than all other methods. The results are in well agreement with earlier findings of Hussain *et al*., (2003). The results obtained during the sowing at spacing of 15 cm and 17.5 cm were found statistically at par with each other. However, a positive effect of closer wheat row spacing in improving outputs was also reported (Farooq *et al*., 2015). Least number of effective tillers was found in crops sown at wider spacing of 22.5cm. Similar results were reported during both years, 2018-19 and 2019-20.

Maximum number of tillers was found in weed free treatments. Among other herbicidal treatments, application of sulfosulfuron + metsulfuron 30 g/ha showed best result in respect of effective tiller number, followed by clodinafop 60 g/ha + metsulfuron 5 g/ha and sulfosulfuron 25 g/ha. Least number of tillers was found in weedy check. This is due to less competition for light, space, moisture and nutrient in weed free environment. Similar results were observed during both year 2018-19 and 2019-20. Interactive effects between various methods and weed control treatments were found to be statistically significant (Table 4.2.7c and 4.2.7d). Effective tillers recorded at the time of harvest during 2018-19 and 2019-20 were significantly higher in bidirectional crop treated with sulfosulfuron +metsulfuron as compared to all other sowing techniques.

4.2.8 Spike length

Spike length has great influence on regulating the number of grains and in turn, the final crop yield. The data revealed that sowing methods significantly influenced the crop yield. Cross sowing produced significantly higher spike length (11.42 and 11.51 cm) [Table 4.2.7a and 4.2.7b] with respect to other sowing methods but remained statistically at par with crops sown at spacing of 17.5 cm. Least spike length was recorded in crop sown with spacing of 22.5 cm. Similar findings were reported by Hussain *et al.* (2017). Different weed control treatments also showed significant effect on spike length. Further, longer spike length was recorded in weed free treatment which was statistical at par with herbicide treatment sulfosulfuron + metsulfuron 30g/ha. This might be due to the fact that weed free treatment resulted in less competition for crops to utilize the available resources up to their full potential (Munoz-Romero *et al*., 2010). Interactive effects between sowing methods and weed control treatments were found to be non-significant with respect to spike length. Similar trends were obtained during both 2018-19 and 2019-20 crop seasons.

4.2.9 Number of grains per spike

The present investigation revealed that different sowing methods significantly influenced the number of grains per spike. It was observed that bi-directional sowing resulted in more (3.40% and 3.37%) number grains per spike than conventional sowing methods (Table 4.2.7a and 4.2.7b). Sowing at spacing 15 cm and 17.5 cm were found to be statistically at par with each other but significantly higher than conventional sowing (spacing of 22.5 cm) in respect of the number of grains per spike. Kaur *et al.,* (2014) also reported similar results as they found 3.7% higher number grains in bi-directional sowing than unidirectional sowing.

Different weed control treatments differed significantly with refers enceto number of grains/spike. Weed free treatments recorded significantly more no. of grains which were statistically at par with herbicide treatment sulfosulfuron + metsulfuron 30 g/ha but significantly higher than other treatments. Herbicides clodinafop 60 g/ha + metsulfuron 5g/ha and sulfosulfuron 25 g/ha were found statistically at par with each other but significantly higher than weedy check. No significant interactions were found between different sowing methods and weed control treatments. Similar trends were found during both 2018-19 and 2019-20 crop seasons.

4.2.10 Test weight

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 stresses, filling pattern etc. The data revealed that different sowing methods significantly influenced the grain weight. Bi-directional sowing caused a higher (3.21% and 3.29%) grain weight than conventional sowing during both years (Table 4.2.7a and 4.2.7b). Sowing at spacing of 15 cm and 17.5 cm resulted an effect on grain weight which was found statistically at par, but significantly more grain weight was recorded in these treatments than conventional sowing (spacing 22.5).Similar results trends were found during both years, 2018-19 and 2019-20 (Table 5.7.a and 5.7.b).

Weed free treatments were found to enhance the grain weight significantly (9.46% and 9.34%) than weedy check (control) during 2018-19 and 2019-20, respectively. The effects found in the herbicidal treatment of sulfosulfuron + metsulfuron 30g/ha were statistically at par with weed free treatment but significantly higher than other treatments. Herbicides clodinafop 60 g/ha + metsulfuron 5 g/ha and sulfosulfuron 25 g/ha treatment were found statistically at par with each other but significantly higher than weedy check. Least grain weight was recorded in weedy check. There were no interactive effects found between sowing methods and weed control treatments.

Table 4.2.7a. Effect of sowing methods and different weed control treatments on effective tillers, spike length, number of panicles and 1000 grain weight during 2018-19 and 2019-20

	Effective tillers/ m^2		Spike length in cm		Number of grains /spike		1000 grain weight (g)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Methods of sowing								
Row spacing 15cm	382.06	382.86	11.00	10.67	50.62	51.66	42.24	43.36
Row spacing 17.5cm	383.13	384.33	11.17	11.18	50.59	51.90	42.24	43.57
Row spacing 22.5cm	368.93	370.60	10.84	10.20	49.47	50.46	41.26	42.60
Bi directional sowing	388.60	389.60	11.42	11.51	51.15	52.08	42.63	44.05
CD 5%	1.22	1.06	0.39	0.79	0.49	0.48	0.16	0.33
Weed control treatment								
Sulfosulfuron 25g/ha	381.66	382.91	11.48	11.00	50.91	52.30	42.57	43.90
Clodinafop 60g/ha followed by metsulfuron 5g/ha	378.83	380.58	10.38	9.90	50.05	51.21	42.08	43.42
Sulfosulfuron + Metsulfuron 30g/ha	386.58	388.08	12.46	12.17	52.19	53.13	43.28	44.61
Weed free	388.33	389.83	12.47	12.45	52.24	53.14	43.32	44.74
Weedy check	368.00	36.83	9.10	8.92	46.89	47.85	39.22	40.56
CD 5%	1.41	0.93	0.32	0.70	0.60	0.66	0.44	0.45
CD interaction	2.91	1.96	NS	NS	NS	NS	NS	NS

Table 4.2.7b. Interaction between sowing methods and weed control treatments on effective tillers per square meter during 2018-19 and 2019-20

Treatment	Sulfosulfuron 25 g/ha	Clodinafop 60 g/ha followed by metsulfuron 5 g/ha	Sulfosulfuron + Metsulfuron 30 g/ha	Weed free	Weedy check	Mean
2018-19						
Row Spacing 15cm	382.33	378.66	388.00	390.66	370.66	382.06
Row Spacing 17.5cm	383.00	379.66	388.66	391.66	372.66	383.13
Row Spacing 22.5cm	370.33	368.33	374.00	374.33	357.66	368.93
Bi-directional sowing	391.00	388.66	395.66	396.66	371.00	388.60
Mean	381.66	378.83	386.58	388.33	368.00	
CD 5%	2.91					
2019-20						
Row Spacing 15cm	384.66	380.33	389.66	393.00	366.66	382.86
Row Spacing 17.5cm	383.66	381.00	390.66	394.00	372.33	384.33
Row Spacing 22.5cm	371.66	370.00	374.66	375.66	361.00	370.60
Bi-directional sowing	391.66	391.00	397.33	396.66	371.33	389.60
Mean	382.91	380.58	388.08	389.83	367.83	
CD 5%	1.96					

4.2.11 Grain yield

The effects of different treatments are ultimately reflected in grain yield. Grain yield is one of the very important economic parameters. Cumulative effect of growth and yield attributing parameters finally decides the grain yield. The grain yield data are shown in Table 4.2.8a and 4.2.8b. Sowing of wheat crop in the bi-direction method as compared to the unidirectional method resulted insignificantly higher grain yield during both 2018-19 and 2019-20 crop seasons. Bi-directional sowing resulted maximum grain yield (47.62 q/ha and 50.46 q/ha) which was significantly higher than conventional sowing (39.54 q/ha and 42.37 q/ha) during 2018-19 and 2019-20, respectively. Higher yield in bi-directional sowing was due to better control of *P. minor* (Table 4.2.4a to 4.2.6), better growth parameters (Table 4.2.1a to 4.2.3b) and higher yield parameters (Table 4.2.7a to 4.2.8d) as compared to other sowing methods. Similar trends were also found in earlier findings (Fonts *et al.*, 1997; Naresh *et al.*, 2014). Ghaffar *et al.*, (2013) found that planting geometry affected the biomass of crop and other yield components of wheat crop, which eventually resulted in higher grain yield; while Kaur *et al.* (2014) found 11% higher grain yield in bi-directional sowing method than unidirectional spacing, even in light soils under optimum conditions.

Yield-related attributes such as number of effective tillers, number of grains per spike, spike length and 1000 grain weight were also observed to increase under bi-directional planting, which was attributed to the efficient utilization of resources like light, water, nutrients etc. as compared to conventional sowing (Devi et al., 2017).

Various weed control treatments also imparted positive significant effects on grain yield. Weed free treatment showed significant higher grain yield (48.81 q/ha and 52.17 q/ha) [Table 4.2.8a and 4.2.8b] during both years than weedy check treatment. Herbicide treatment of sulfosulfuron + metsulfuron 30 g/ha was found statistically at par with weed free treatment but significantly better than other herbicidal treatments. Further, treatment of sulfosulfuron 25 g/ha was found to be statistically more effective than clodinafop 60 g/ha + metsulfuron 5 g/ha. Increase in grain yield with application of different herbicides might be due to higher weed control efficiency and lesser crop-weed competition which resulted in better utilization of resources by crop in weed free treatment than weedy treatment (Meena and Singh 2013); Ali *et al.*, 2016). The interactions between sowing methods and weed control treatments were found to be significant. Different weed control treatments in bi-directional planting were found to be significantly better than that of the conventional sowing at spacing of 22.5 cm. Weed control treatments with spacing of 17.5 cm showed statistically similar results as evidenced with cross sowing. Bi-directional sowing was reported to be promising in weed suppression and more crop smothering effect that resulted in higher yield attributes (Singh *et al*., 2013).The interactive effects between sowing methods and weed control treatments for grain yield were found to be significant during 2018-19 and 2019-20 (Table 4.2.8c). Application of sulfosulfuron + metsulfuron in bi-directional sowing produced significantly higher grain yield than that with application of sulfosulfuron 25 g/ha and clodinafop 60 g/ha followed by metsulfuron 5 g/ha treatment when applied on crop sown at 15 cm ,17.5 cm and 22.5 cm row to row spacing. This holds good for both years of experimentation.

4.2.12 Straw yield

Straw yield is important component of total biological yield. The data of straw yield is shown in Table 4.2.8a and 4.2.8b. The present investigation revealed that sowing methods significantly influenced the straw yield during both cropping seasons, 2018-19 and 2019-20. Bi-directional sowing showed significantly higher straw yield as compared to unidirectional sowing. Hussain *et al.* (2017) also reported the same result. The results obtained in crops sown at spacing of 17.5 cm and 15 cm were statistically at par. Least biological yield was recorded in crops sown at a spacing of 22.5 cm.

It has been observed in the present study that different treatments for weed control exhibited a significant influence over biological yield of the crop. Weed free treatment recorded higher straw yield in comparison with other treatments. Between herbicidal treatments, sulfosulfuron + metsulfuron 30 g/ha yielded significantly higher straw yield than sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5 g/ha. Increase in straw yield by different weed control treatments could be due to higher plant height, more dry matter accumulation and overall better growth and development of crop (Singh *et al*., 2010; Meena and Singh (2013); Ali *et al*., 2016).The interactions between sowing methods and weed control treatments were found to be significant. Different weed control treatments in bi-directional sowing were significantly better than the conventional sowing at spacing of 22.5 cm. similar research trend was found during both years, 2018-19 and 2019-20 (Table 4.2.8d)

4.2.13 Harvest index (HI)

Data revealed better HI in bi-directional crop sowing as compared to single directional sowing. The results confirm the findings of Hussain *et al.*, (2017). Lower HI was recorded in crops sown in conventional sowing at a spacing of 22.5 cm. Crops sown at spacing of 15 cm and 17.5 cm exhibited slightly better HI over conventional sowing method.

Between various treatments for weed control, weed free treatment showed higher HI, followed by herbicide treatment sulfosulfuron + metsulfuron 30 g /ha which was followed by sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5 g/ha. Lower HI was recorded in weedy check (unweeded control). Overall, more economic and biological yields in terms of grain and straw yield due to better WCE in different weed control treatments than weedy check treatment were observed during both 2018-19 and 2019-20 crop seasons (Table 4.2.8a and 4.2.8b).

Table 4.2.8a. Effects of sowing methods and different weed control treatments on grain yield, straw yield, and harvest index (HI) during 2018-19 and 2019-20

	Grain q/ha		Straw q/ha		HI	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Dates of sowing						
Row spacing 15cm	41.53	45.32	60.6	64.6	40.66	41.22
Row spacing 17.5cm	42.85	46.42	62.04	65.96	40.85	41.30
Row spacing 22.5cm	39.54	42.37	58.9	62.06	40.16	40.57
Bi directional sowing	47.62	50.46	66.99	69.92	41.54	41.91
CD 5%	1.63	2.41	1.79	2.36		
Weed control treatment						
Sulfosulfuron 25g/ha	43.46	46.83	62.75	66.2	40.91	41.43
Clodinafop 60g/ha followed by metsulfuron 5g/ha	42.08	45.29	61.25	64.61	40.72	41.21
Sulfosulfuron + Metsulfuron30g/ha	47.58	50.85	66.86	70.5	41.57	41.90
Weed free	48.81	52.17	68.08	71.71	41.75	42.11
Weedy check	32.49	35.57	51.73	55.15	38.57	39.20
CD 5%	1.24	1.23	1.32	1.3		
CD interaction	2.64	2.7	2.8	2.85		

Table 4.2.8b. Interaction between sowing methods and weed control treatments on grain yield (q/ha) during 2018-19 and 2019-20

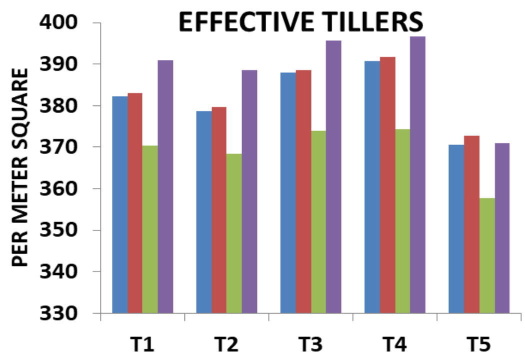
Treatment	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
2018-19						
Row Spacing 15cm	43.13	40.93	46.23	48.80	28.56	41.53
Row Spacing 17.5cm	43.20	42.53	46.56	49.23	32.73	42.85
Row Spacing 22.5cm	39.93	39.03	44.76	44.83	29.13	39.54
Bi-directional Sowing	47.60	45.83	52.76	52.40	39.53	47.62
Mean	43.46	42.08	47.58	48.81	32.49	
CD 5%	2.64					
2019-20						
Row Spacing 15cm	46.96	44.43	50.06	53.06	32.06	45.32
Row Spacing 17.5cm	47.16	46.20	50.13	52.73	35.90	46.42
Row Spacing 22.5cm	42.76	41.86	47.60	47.66	31.96	42.37
Bi-directional Sowing	50.43	48.66	55.60	55.23	42.36	50.46
Mean	46.83	45.29	50.85	52.17	35.57	
CD 5%	2.70					

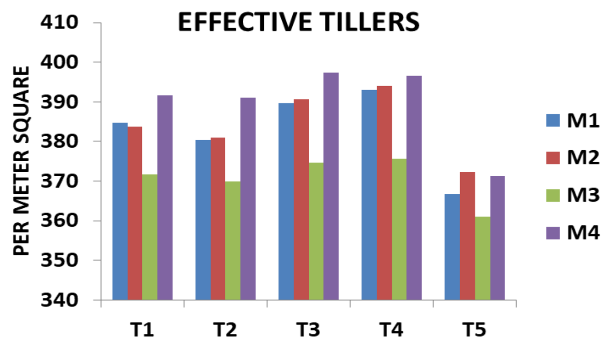
Table 4.2.8.c. Interaction between sowing methods and weed control treatments on straw yield (q/ha) during 2018-19 and 2019-20

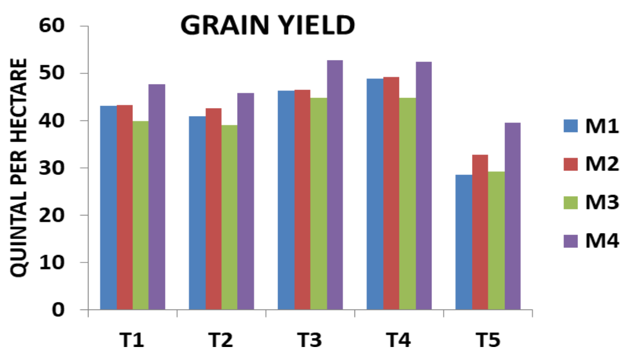
Treatments	Sulfosulfuron 25g/ha	Clodinafop 60g/ha followed by metsulfuron 5g/ha	Sulfosulfuron + Metsulfuron 30g/ha	Weed free	Weedy check	Mean
2018-19						
Row Spacing 15cm	62.50	60.03	65.26	67.76	47.43	60.60
Row Spacing 17.5cm	62.23	61.36	65.93	68.60	52.10	62.04
Row Spacing 22.5cm	59.30	58.40	64.13	64.20	48.50	58.90
Bi-directional Sowing	66.96	65.20	72.13	71.76	58.90	66.99
Mean	62.75	61.25	66.86	68.08	51.73	
CD 5%	2.80					
2019-20						
Row Spacing 15cm	66.26	62.73	69.73	72.90	51.40	64.60
Row Spacing 17.5cm	66.03	65.86	69.96	72.40	55.56	65.96
Row Spacing 22.5cm	62.43	61.53	67.400	67.33	51.63	62.06
Bi-directional Sowing	70.10	68.33	74.933	74.23	62.03	69.92
Mean	66.20	64.61	70.508	71.71	55.15	
CD 5%	2.85					

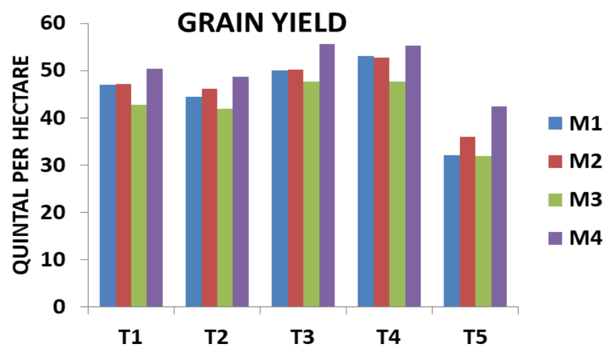
Fig .4.6 Interactive effect of sowing methods and different weed control treatment on effective tillers, grain yield and straw yield during year 2018-19 and 2019-20.

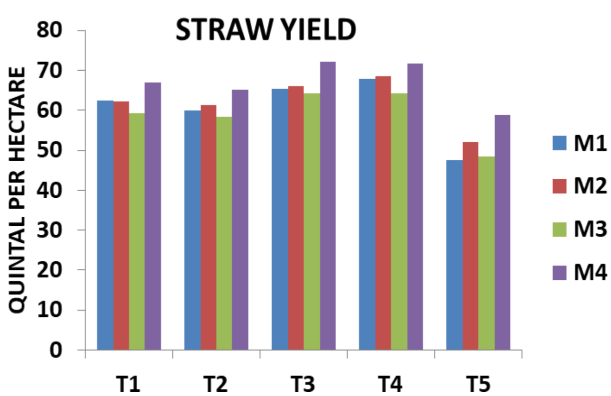
2018-19	2019-20

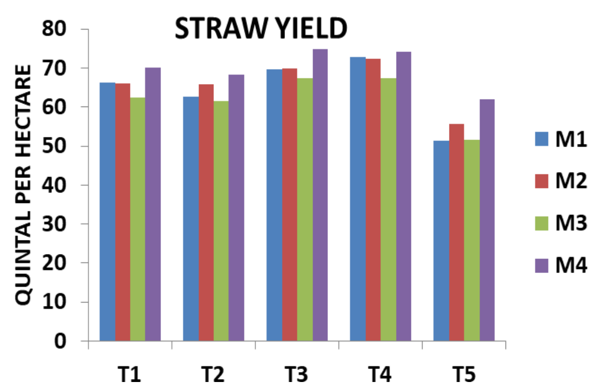












M1: Row Spacing 15cm,M2: Row Spacing 17.5cm, M3: Row Spacing 22.5cm, M4: Bi-directional sowing T1: sulfosulfuron 25g/ha, T2: clodinafop 60g/ha fb metsulfuron 5g/ha, T3:sulfosulfuron 30g/ha, T4: weed free, T5: weedy check

Soil analysis

4.2.14 Organic carbon (OC)

Different sowing methods exerted non-significant effect on the soil OC content and they remained statistically at par with each other when soil analysis was done after collecting soil at harvest. OC content is directly related to organic matter and humus present in soil. Different treatments for weed control were also found to exert non-significant effect on soil OC content. This explains the fact of non-interference of these treatments on the soil organic matter or humus. Similar results were observed by Brar *et al*. (2019). Results trend were similar during both 2018-19 and 2019-20 crop seasons (Table 4.2.9a and 4.2.9b). No interaction effect among sowing method and treatments for weed control on soil OC was observed.

4.2.15 Available nitrogen (N)

The data recorded from post-harvest analysis of soil revealed that soil available N content was not influenced by the different sowing methods. This might be due to similar fertilizer doses applied to all treatments. However, available N content were found to be significantly influenced by the different treatments for weed control. All treatments for weed control showed significantly higher available N content in comparison with weedy check treatment. Weed free treatment exhibited higher available N content followed by herbicide treatment sulfosulfuron + metsulfuron 30 g/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5 g/ha. Weedy check (control) recorded significantly lower available N content as compared to other treatments. This might be due to higher uptake of N by weeds in unweeded treatment. Higher uptake of N by weeds was also reported by Brar and Walia (2008). In the present study, same trend was observed during both 2018-19 and 2019-20 crop seasons. No interaction effect between sowing method and weed control treatments on soil available N content was observed.

4.2.16 Available phosphorus (P)

Post-harvest analysis of soil revealed that sowing methods had no significant effect to influence the available P content in soil. Results were similar during both 2018-19 and 2019-20 crop seasons. However, all weed control treatments increased available P content in soil significantly as compared to control treatment (unweeded). To increase soil available P content, weed free treatment provided the best result followed by herbicide treatment sulfosulfuron + metsulfuron 30 g/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5 g/ha in a sequential manner but all are statistically at par with each other. This might be due to more mining of nutrient from unweeded (control) treatment and resulted in lowering the available P content. Similar results were reported by Brar *et al.*, (2019). Interaction effect between weed control and sowing method treatments on soil available P content was recorded to be non-significant. Similar research trends were observed in years, 2018-19 and 2019-20.

4.2.17 Available potassium (K)

Non-significant effects of different sowing methods on available K content in soil were observed, when post-harvest soil samples were analyzed. Results obtained for all sowing methods were statistically at par with each other during both years 2018-19 and 2019-20 (Table 4.2.9a and 4.2.9b). However, various weed control treatments increased the available K content in soil significantly. Weed free treatment showed higher available K content in soil followed by herbicide treatment sulfosulfuron + metsulfuron 30 g/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha +metsulfuron 5g/ha. Least K content was observed in weedy check treatment (control). This might be due to more uptakes of K by weeds from unweeded treatment. Similar results were reported by Brar *et al*,. (2019). Interactive effects between sowing methods and weed control treatments were found to be non-significant. Similar research trends were observed in both years, 2018-19 and 2019-20.

Table4.2.9. Effect of date of sowing and different weed control treatments on organic carbon (OC), available nitrogen (N), available phosphorus (P) and available potassium (K) in soil during 2018-19 and 2019-20

	OC (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Methods of sowing								
Row spacing 15cm	0.44	0.44	180.53	181.80	15.95	16.38	157.73	160.73
Row spacing 17.5cm	0.44	0.45	180.40	180.40	15.26	15.86	156.73	159.73
Row spacing 22.5cm	0.44	0.44	180.33	182.46	15.24	15.66	155.53	158.53
Bi directional sowing	0.45	0.45	180.73	183.53	16.08	16.40	157.3	161.33
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS
Weed count treatment								
Sulfosulfuron 25g/ha	0.44	0.45	181.25	183.50	15.66	16.17	157.33	159.08
Clodinafop 60g/ha followed by metsulfuron 5g/ha	0.44	0.44	180.75	182.83	15.63	16.09	154.66	158.00
Sulfosulfuron + Metsulfuron 30g/ha	0.45	0.45	182.00	184.83	15.91	16.47	160.58	163.33
Weed free	0.45	0.46	182.66	184.91	16.20	16.85	162.25	165.25
Weedy check	0.44	0.44	175.83	177.91	14.76	14.80	150.00	154.75
CD 5%	NS	NS	2.18	2.96	0.78	0.88	2.13	2.66
CD interaction	NS	NS	NS	NS	NS	NS	NS	NS

Experiment: 3

Efficacy of herbicides to control different resistant biotypes of *Phalaris minor*

4.3.1. Plant height of *P. minor*

Significant differences in plant height of different biotypes of *Phalaris minor* during both years of 2018-19 and 2019-20 were observed (Table 4.3.1a and 4.3.1b). B_1 and B_2 biotypes exhibited significant higher plant height over the other biotypes. B_4 and B_5 biotype showed numeric edge in height over B_3 biotype but statistically all are at par with each other. Least plant height was recoded in biotype B_3. Variable behavior of different *Phalaris minor* biotypes with reference to plant height was also observed by Malik and Singh (1995). Significant influence on the plant height of *P. minor* was exerted by different herbicidal treatments. Metribuzine recorded least *P.minor* height in comparison with other treatments but it was statistically at par with metribuzine + clodinafop propanyl. Maximum *P.minor* biotype's height was recorded by control treatment. No significant interactions were observed between *P.minor* plant height and herbicides treatments. Similar trends were observed during both year 2018-19 and 2019-20.

4.3.2 Tillers of *P. minor* per row length

Tillers are the important growth attributes that influence the final dry matter accumulation. Significant differences in number of tillers within different biotypes were observed (Table 4.3.1a and 4.3.1b). B_1 and B_2 biotypes recorded higher number of tillers with respect to other biotypes but both are statistically at par with each other. Similar trends were observed in second year also, that confirms the edging of B_1 and B_2 biotypes in number of tillers over the others. Malik and Singh (1995) also observed variable number of tillers with respect to different biotypes. Different herbicidal treatments exhibited significant influence on the number of tillers in *P.minor*. Metribuzine recorded smaller number of tillers in comparison with other treatments but metribuzine treatment was found statistically at par with metribuzine + clodinafop propanyl. This establishes the fact of superiority of metribuzine application alone or in combination with clodinafop propanyl over the other treatments in exerting its herbicidal effect. Maximum numbers of tillers were recorded in control treatment. No significant interactions were observed between number of tillers and herbicidal treatments. Similar trends were observed during both years of 2018-19 and 2019-20.

4.3.3 Number of leaves

Although B_1 and B_2 biotypes recorded numerically a greater number of leaves but statistically they were at par with each other. All biotypes showed the same number of leaves at harvest during both years, 2018-19 and 2019-20. However, different herbicidal treatments were found to exert significant effects on the leaves of *P. minor*. Herbicide treatment metribuzine reduced the leaf number per plant significantly as compared to other treatments. Maximum numbers of leaves were recorded by control treatment. Metribuzine resulted in maximum loss of leaves, followed by the application of metribuzine + clodinafop propanyl which, in turn, exerted significantly more effects than rest of other treatments. However, no interactive effects were observed between number of leaves of different biotypes of *P. minor* and herbicide treatments. Similar trends were observed during both years, 2018-19 and 2019-20 (Table 4.3.1a and 4.3.1b).

Table 4.3.1. Efficacy of herbicides to control different biotypes of Phalaris minor in respect with their plant heights, number of tillers and number of leaves during 2019-20

	Height (cm)		**Tillers**		**Leaves**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Biotypes						
Biotype B_1	70.90	72.53	93.41	96.60	4.66	4.83
Biotype B_2	69.40	71.22	94.20	96.56	4.68	4.86
Biotype B_3	64.62	66.30	88.56	89.98	4.44	4.72
Biotype B_4	66.37	67.98	86.81	88.01	4.50	4.77
Biotype B_5	65.97	67.69	86.11	87.31	4.33	4.50
CD 5%	1.56	1.36	4.71	5.16	NS	NS
Weed control treatment						
Sulfosulfuron 25g/ha	70.56	71.95	120.13	122.09	5.53	5.65
Clodinafop 60g/ha	68.30	69.84	111.36	113.29	4.86	5.06
Sulfosulfuron + Metsulfuron 30g/ha	66.12	67.90	106.00	107.28	4.66	4.82
Metribuzine + Clodinafop propanyl 54 g/ha	59.35	60.95	26.57	28.38	3.33	3.53
Metribuzine 175 g/ha	57.98	60.17	20.94	23.50	2.46	2.54
Weedy check	82.42	84.06	153.91	155.62	6.26	6.79
CD 5%	1.63	1.50	5.79	5.73	0.578	0.371
CD interaction	NS	NS	NS	NS	NS	NS

4.3.4. Number of panicle

In both year of field experimentation, 2018-19 and 2019-20, B_1 and B_2 biotypes recorded more panicles than other biotypes and they both are statically at par with each other (Table 4.3.2a and 4.3.2b).When panicles number were obtained in weedy check was compared with that of the different herbicidal treatments, herbicides were found to exert inhibitory effect of the panicle development and they reduced the number of panicles significantly. Least number of panicles were recorded in herbicide treatment metribuzine as compared to other treatments except the treatment of metribuzine + clodinafop propanyl, where the effects were found statistically at par. Maximum numbers of panicles were recorded in control treatment. No significant interactions were observed between number of panicles and herbicides treatments. Similar trends were observed during both years, 2018-19 and 2019-20.

4.3.5 Panicles length of *P.minor*

Data revealed that there was no statistical difference in panicle length among different biotypes. Walia *et al.,* (1997) found same results. Similar trends were observed during both years, 2018-19 and 2019-20 (Table 4.3.2a and 4.3.2b). However, different herbicide treatments significantly influenced the panicle length of *P. minor* in reducing the panicle length as compared to the control. Panicle length was found maximum in control treatment (unsprayed). Among different herbicide treatments, metribuzine + clodinafop propanyl and metribuzine alone resulted in maximum reduction in panicle length; however, the effects of both treatments in reducing the panicle length remained statistically same. Interaction between different biotypes and herbicides treatments was found to be non-significant. Similar trends were observed during both years, 2018-19 and 2019-20.

4.3.6 Dry matter (DM) accumulation

Maximum DM accumulation was recorded in biotype B_2 which was significantly higher than other biotypes (Table 4.3.2a and 4.3.2b). Least amount of DM was found in biotype B_5. Similar results were recorded during both years, 2018-19 and 2019-20.Different morphological behaviors of *P. minor* biotypes under noncompetitive conditions were found by Dhaliwal *et al*. (1998). All herbicidal treatments were found to reduce the DM content significantly in comparison with weedy check. Among all herbicidal treatments metribuzine + clodinafop propanyl and metribuzine were observed to exert more significant effect in reducing DM accumulation with respect to other treatments. However, their effects were found statistically at par. Similar results were observed during both years. Application of metribuzine with other herbicides proved effective against cross resistance biotypes of *P. minor* (Yadav *et al*., 2016). Interactive effects between different biotypes and herbicide treatments were found to be statistically significant. Among different herbicides treatments, metribuzine + clodinafop propanyl and Metribuzine resulted in significantly less DM accumulation in all biotypes of *P.minor*. All biotypes of *P. minor* produced significantly lower DM production with the application of metribuzine + clodinafop propanyl and metribuzine, but both treatments were statistically at par with each other in exerting their effects. Results were similar during years, 2018-19 and 2019-20 (Table 6.2.c and 6.2.d)

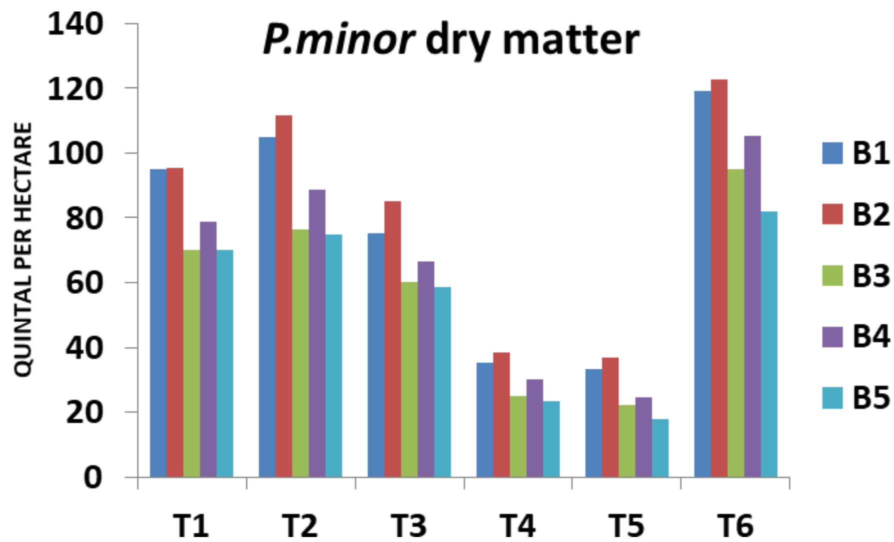
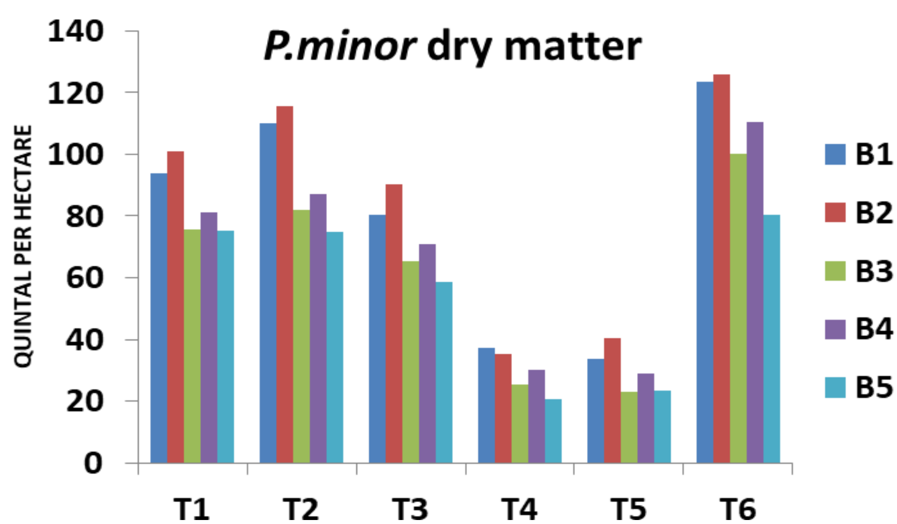
Table 4.3.2a. Efficacy of herbicides to control different biotypes of Phalaris minor in respect with their number of panicles, panicle length and dry matter production during 2018-19 and 2019-20

	Number of panicles		**Panicle length (cm)**		**Dry matter (q/ha)**	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Biotypes						
Biotype B_1	79.99	80.31	3.29	3.74	77.11	79.75
Biotype B_2	81.13	83.26	3.56	3.87	81.71	84.67
Biotype B_3	73.81	75.07	3.44	3.88	58.15	61.95
Biotype B_4	74.02	73.56	3.30	3.63	65.61	68.16
Biotype B_5	67.43	68.34	3.44	3.46	54.48	55.58
CD 5%	4.21	4.75	NS	NS	3.13	4.81
Weed control treatment						
Sulfosulfuron 25g/ha	92.84	92.93	3.73	4.17	81.87	85.32
Clodinafop 60g/ha	96.62	97.42	3.77	4.04	91.34	93.94
Sulfosulfuron + Metsulfuron 30g/ha	87.44	87.37	3.70	3.97	69.10	73.12
Metribuzine + Clodinafop propanyl 54 g/ha	17.08	17.75	2.30	2.60	30.44	29.78
Metribuzine 175 g/ha	14.04	16.16	2.22	2.50	26.92	29.89
Weedy check	143.64	144.01	4.72	5.13	104.81	108.10
CD 5%	4.03	4.84	0.34	0.42	3.69	4.48
CD interaction	NS	NS	NS	NS	8.41	10.31

Table 4.3.2b. Interaction effects between biotypes and herbicidal treatments on dry matter (DM) accumulation in *Phalaris minor*

Phalaris minor DM (q/ha)							
Biotypes	**Sulfosulfuron 25g/ha**	**Clodinafop 60g/ha**	**Sulfosulfuron + Metsulfuron 30g/ha**	**Metribuzine + Clodinafop propanyl**	**Metribuzine**	**Weedy check**	**Mean**
2018-19							
Biotype B_1	94.83	105.00	75.10	35.23	33.20	119.33	77.11
Biotype B_2	95.53	111.73	85.06	38.50	36.80	122.67	81.71
Biotype B_3	70.20	76.53	60.13	24.86	22.10	95.06	58.15
Biotype B_4	78.73	88.53	66.73	30.00	24.53	105.16	65.61
Biotype B_5	70.06	74.90	58.50	23.60	18.00	81.83	54.48
Mean	81.87	91.34	69.10	30.44	26.92	104.81	
CD 5%	8.41						
2019-20							
Biotype B_1	93.67	110.16	80.46	37.10	33.66	123.46	79.75
Biotype B_2	100.83	115.40	90.23	35.36	40.43	125.80	84.67
Biotype B_3	75.533	81.90	65.36	25.60	23.10	100.23	61.95
Biotype B_4	81.33	87.20	70.73	30.28	28.93	110.50	68.16
Biotype B_5	75.23	75.03	58.83	20.56	23.33	80.50	55.58
Mean	85.32	93.94	73.12	29.78	29.89	108.10	
CD 5%	10.31						

Fig .4.7 Interaction effects between biotypes and herbicidal treatments on *Phalaris minor* dry matter accumulation at harvest during year 2018-19 and 2019-20.

2018-19

2019-20

B1: Biotype 1, B2:Biotype 2, B3: Biotype 3, B4: Biotype, B5: Biotype 5, T1: sulfosulfuron 25g/ha, T2: clodinafop 60g/ha fb metsulfuron 5g/ha, T3:sulfosulfuron 30g/ha, T4: Metribuzine + Clodinafop propanyl, T5: Metribuzine, T6: control.

Summary and conclusion

The field experiment entitled "**Performance of herbicides to control *Phalaris minor* Retz. as influenced by date of sowing and planting pattern of wheat (*Triticum aestivum* L.*)*"**was conducted at the research farm of Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara (Punjab) during the *rabi* season of 2018-2019 and 2019-2020. The result has been summarized as below:

Experiment-1 Effect of date of sowing and weed control treatments on growth and development of wheat and associated weeds.

Weedy check produced significantly lowest dry matter accumulation than all other weed control treatments. Data recorded at 30 DAS was found to be a non-significant, because herbicide application was done at 30 DAS. Weed infestation in the experimental field directly influences the total crop yield. Counts of *Phalaris minor* were recorded periodically at 30, 60, 90 DAS and at harvest (panicles only). Significantly less number of weed per square meter was observed for first date of sowing (1^{st} November) in comparison to 2^{nd} (20^{th} November) and 3^{rd}date of sowing (10^{th} December). Higher weed population was recorded in weedy check which was significantly more than other weed control treatments during both the years of study. *P.minor* population was found to be zero in weed free treatment**.** Data recorded at 90 DAS and at harvest, among different weed control treatments, showed significantly less dry matter accumulation in crop sown on 1^{st}November than the crop sown on 10^{th} December. Application of sulfosulfuron + metsulfuron 30 g/ha produced significantly less dry matter of *P. minor* on 1^{st} November sown crop as compared to other herbicidal treatments on all dates of sowing during 2019-20 crop season. Among different treatments for weed control, highest efficiency was found in weed free treatment which is followed by herbicide treatment sulfosulfuron + metsulfuron 30g a/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5 g/ha. Similar trend was observed in both year i.e. 2018-19 and 2019-20.

The wheat plant growth and development were significantly influenced by date of sowing. Sowing of crop at recommended time 1st November increased the yield and yield attributes of wheat. Weed control treatments decreased the density of weeds and the plant population per unit area. Plant height is very important growth parameter governing the crop yield. The plant height was recorded at 30 DAS, 60 DAS ,90 DAS and at harvest. The first date of sowing (1stNovember) was found to be felicitous sowing time. This may be due to the better utilization of light, nutrient and moisture. All weed control treatments significantly exerted higher plant height as compared to unweeded (control) treatment when recorded at 60, 90 days after sowing and at harvest. Significantly higher plant height was recorded at all periodic intervals (except 30 DAS) with the post emergence application of sulfosulfuron + metsulfuron 30 g/ha as compared to application of sulfosulfuron 25 g/ha and clodinafop 60 g./ha followed by metsulfuron 5 g/ha. Due to more density of weeds, least plant height was recorded in weedy check. Crop sown on November 1st, 2019 recorded significantly higher plant height than other dates of sowing. Also, among sub-plot treatments, application of sulfosulfuron + metsulfuron was found to record significantly higher plant height than other herbicidal treatments at all periodic intervals. The number of tillers per unit area is considered as one of the major determinants for the crop growth and yield. Number of total tillers were counted at 30, 60, 90 DAS and effective tillers at harvest stage. Total effective tillers recorded at 60, 90 DAS and at harvest were found to be significantly higher in 1stNovember sown crop as compared to 20th November and 10th December sown crop, that may be due to congenial climatic condition which prevailed during November. Higher total number of tiller at 60 DAS, 90 DAS and at harvest (effective) stage were found to be more in weed free treatment as compared to other weed control treatments and it was followed by sulfosulfuron + metsulfuron 16 g/ha, sulfosulfuron 13 g/ha and clodinafop 60 g/ha+ metsulfuron 5 g/ha. Dry matter accumulation by crop influences the final crop yield, as it also reflects on the photosynthetic accumulation. Different dates of sowing were found to be non-significant at 30 DAS with respect to crop dry matter production. However, data recorded at 60, 90 DAS and at harvest were found to be significantly higher at first date of sowing i.e. 1st November as comparedto crop sown on 20th November and 10th December during both year of study. Crop dry matter accumulation was significantly affected by different weed control treatment at 60 DAS, 90 DAS and at harvest.

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It was observed in the present study that numbers of effective tillers were significantly influenced by date of sowing. Crop sown at firsts date of sowing i.e 1stNovember produced significantly more tillers than that in crop sown on second and third date of sowing. Effective tillers were significantly influenced by various treatments for weed control. Out of all three herbicidal treatments, sulfosulfuron + metsulfuron 30 g/ha produced significantly higher spike length than weedy check but remained statistically at par with weed free treatment. The pattern of the results was similar during both 2018-19 and 2019-20 crop seasons. Crops sown on 1st November exhibited significantly maximum number of grains per spike that was significantly higher than that of crops sown on 20th November and 20th December. Total number of grains was significantly influenced by different treatments that were used for weed control. Weed free treatment recorded higher number of grains/spike which was statistically at par with herbicide treatments sulfosulfuron + metsulfuron 30 g/ha. The test weight of crop sown on 1st November was found to be non-significant with the crop sown on 20th November and 10th December during both the years of study.

Weed control treatment also showed the significant effect on the grain yield. From all the weed control treatments, higher grain yield (49.55 q/ha and 47.12 q/ha in 2018-19 and 2019-20, respectively was found in weed free treatment and this treatment remained statistically alike with (47.86q/ha and 46.78q/ha) with herbicide treatment sulfosulfuron + metsulfuron 30 g/ha but showed significantly higher grain yield than other weed control treatments. Herbicide treatment ofsulfosulfuron + metsulfuron 30 g/ha was found to exhibit significantly higher grain yield (43.03%,and 36.26.10%) than weedy check. Treatment of sulfosulfuron + metsulfuron 30g/ha led to poor weed growth which eventually increased the number of effective tillers, number of grains per spike and test weight.

Experiment-2 Effect of sowing methods and weed control treatments on growth and development of plants and weeds

Phalaris minor counts were recorded at 30, 60, 90 DAS and at harvest. At 60, 90 DAS and at harvest bi-directional sowing decreased population of *P.minor* significantly as compared to single directional sowing at different spacing. Followed by bi-directional sowing, crops sown at spacing of 15 cm resulted in more suppression of *P. Minor* population than crops sown at spacing of 17.5 cm and 22.5 cm. Maximum numbers of *P.minor* weeds were recorded in crops sown at broader spacing of 22.5 cm. Weed population was zero in weed free treatment**.** Post-emergence application of sulfosulfuron + metsulfuron 30 g/ha showed significantly a smaller number of *P. minor* than the applications of sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5 g/ha. During 2018-19 and 2019-20, higher weed control efficiency (73.01 % and 72.48 %) was obtained in bi-directional sowing as compared to crops sown at spacing of 15 cm, 17.5 cm and 22.5 cm in single direction. Least weed control efficiency (66.05 and 65.95) was found in crop sown at spacing of 22.5 cm. Weed free treatment recorded higher weed control efficiency which followed by herbicides treatment sulfosulfuron + metsulfuron 30 g/ha, sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron 5 g/ha. Similar research trends were observed during 2018-19 and 2019-20 crop seasons. The growth and development of plants and the density of weed population might be influenced by sowing methods. Bi-directional sowing due to appropriate spacing between plants increased the yield and yield attributes of wheat. Sowing and weed control methods influenced plant height. The difference in plant height due to different sowing methods was found to be non-significant when recorded at 30 DAS. The plant height recorded at 60 DAS, was found to be significantly higher in bi-directional sowing as compared to the crop sown at spacing of 15 cm, 17.5 cm and 22.5 cm as unidirectional. However, the plant height of crop sown at spacing of 15 cm and 17.5 cm was found to be statistically at par, but was significantly more than the crop sown at spacing of 22.5 cm. All weed control treatments recorded significantly higher plant height as compared to unweeded (control) treatment at 60 DAS, 90 DAS and at harvest. Among herbicidal treatment, significantly higher plant height was recorded at all periodic intervals (except 30 DAS) with the application of post-emergence herbicide (sulfosulfuron + metsulfuron 30 g/ha) as compared to the application of sulfosulfuron 25 g/ha and clodinafop 60 g/ha followed by metsulfuron 5 g/ha.

These observations hold good during both the years of study. Number of tillers is considered as a crucial growth parameter which influences the final yield. The total number of tillers has been recorded at different periodic intervals of 30 DAS, 60 DAS, 90 DAS. Maximum numbers of tillers per square meter were found in bi-directional sowing. Bi-directional sowing evenly distributed the seeds with definite spatial pattern which encouraged proper utilization of natural sources than the conventional methods. Number of tillers was positively influenced by various weed control treatments. Maximum number of tillers was found in weed free treatment followed by herbicide treatment of sulfosulfuron + metsulfuron 30 g/ha which produced statistically significant higher number of tillers than other herbicide treatments. Lowest number of tillers was found in weedy check. Crop dry matter is important pre-harvest growth parameter which has great influence on final crop yield. At 60 DAS, 90 DAS and at harvest, Dry matter (DM) accumulation in crops ,sown at spacing of 17.5 cm and 15 cm, was statistically at par with each other but significantly higher than that of the crops sown at 22.5 cm. Among all weed control treatments, weed free treatment produced significantly higher DM as compared to other treatments. At 60 DAS, DM accumulation in weed free treatment and herbicide treatments of sulfosulfuron + metsulfuron 30 g/ha was statistically at par with each other but significantly higher than other treatments. At 90 DAS and at harvest, DM accumulation in weed free treatments was found to be significantly better than other treatments and it was followed by sulfosulfuron + metsulfuron 30 g/ha.

Effective tillers directly influence the final crop yield. With increasing effective tillers, the crop yield usually increases. Bi-directional sowing recorded significantly more tillers than all other methods. The results obtained with spacing of 15 cm and 17.5 cm were found statistically at par with each other. Least number of effective tillers was found in crops sown at wider spacing of 22.5 cm. Similar results were reported during both years, 2018-19 and 2019-20. Spike length has great influence on regulating the number of grains and, in turn, the final crop yield. The data revealed that sowing methods significantly influenced the crop yield. Cross sowing produced significantly higher spike length (11.42 and 11.51 cm) during both years, 2018-19 and 2019-20 with respect to other sowing methods. Least spike length was recorded in crop sown with spacing of 22.5 cm. Different sowing methods significantly influenced the number of grains per spike. It was observed that bi-directional sowing resulted in (3.40 % and 3.37 %) higher number grains per spike than conventional sowing methods. Sowing at spacing 15 cm and 17.5 cm were found to be statistically at par with each other but significantly higher than conventional sowing (spacing of 22.5cm). Among various weed control treatments, weed free treatment were found to enhance the grain weight significantly (9.46 % and 9.34 %) than weedy check (control) during both years. The effects found in the herbicidal treatment of sulfosulfuron + metsulfuron @ 30 g/ha were statistically at par with weed free treatment but significantly higher than other treatments. Clodinafop 60 g/ha + metsulfuron 5 g/ha and sulfosulfuron 25 g/ha treatments were found statistically at par with each other but significantly higher than weedy check. Least grain weight was recorded in weedy check.

Grain yield is one of the very important economic parameters. Cumulative effect of growth and yield attributing parameters finally decides the grain yield. Sowing of wheat crop in the bi-direction method as compared to the unidirectional method resulted significantly higher grain yield during both 2018-19 and 2019-20 crop seasons. Bi-directional sowing resulted maximum grain yield (47.62 q/ha and 50.46 q/ha) which was significantly higher than conventional sowing (39.54 q/ha and 42.37 q/ha) during 2018-19 and 2019-20, respectively. Higher yield in bi-directional sowing was due to better control of *P.minor*. The higher grain yield was observed in the application of sulfosulfuron + metsulfuron 30 g/ha in bi-directional sowing than that with application of sulfosulfuron and clodinafop followed by metsulfuron treatment, when the herbicides were applied on crop sown at 15 cm, 17.5 cm and 22.5 cm row to row spacing. This holds good for both years of experimentation.

Straw yield is important component of total biological yield. The present investigation revealed that sowing methods significantly influenced the straw yield during both 2018-19 and 2019-20 cropping seasons. Bi-directional sowing showed significantly higher straw yield as compared to unidirectional sowing. The results obtained in crops sown at spacing of 17.5 cm and 15cm were statistically at par. Least biological yield was recorded in crops sown at a spacing of 22.5 cm. Among herbicidal treatments, treatment of sulfosulfuron 25 g/ha yielded maximum straw yield than clodinafop 60 g/ha + metsulfuron 5 g/ha. Increase in straw yield by different weed control treatments could be due to more DM accumulation, increase in plant height, and overall better growth and development of crop. Better harvesting index was found in bi-directional crop sowing as compared to unidirectional sowing. Lower HI was recorded in crops sown in conventional sowing at a spacing of 22.5 cm. Crops sown at spacing of 15 cm and 17.5 cm exhibited slightly better HI over conventional sowing method. Among various weed control treatments, weed free treatment showed higher HI, followed by herbicide treatment sulfosulfuron + metsulfuron 30 g/ha which was followed by sulfosulfuron 25 g/ha and clodinafop 60 g/ha + metsulfuron

5g/ha.

Experiment-3 Efficacy of herbicides to control different resistant biotypes of *Phalaris minor*

In rice-wheat cropping system, *P. minor* is the troublesome weed. Application of various herbicides results in resistance in *P. minor*. Significant difference in plant height of different biotypes of *Phalaris minor* which were collected from farmer's field during both years of 2018-19 and 2019-20 was observed. $B_1$and B_2biotypes exhibited significantly higher plant height over the other biotypes. B_4 and B_5 biotype showed numeric edge in height over B_3 biotype but statistically all are at par with each other. Least plant height was recorded in biotype B_3. Metribuzine recorded least height of *P.minor* biotypes in comparison with other treatments but it was statistically at par with metribuzine + clodinafop propanyl. Maximum *P.minor* biotype's height was recorded by control treatment. Tillers are the important growth attributes which influences the final dry matter accumulation. Significant differences in number of tillers within different biotypes were observed. B_1 and B_2 biotypes recorded higher number of tillers with respect to other biotypes but both are statically at par with each other. Similar trends were observed in second year also, that confirms the edging of B_1 and B_2 biotypes in tillers' number over the others. The tillers' number in *Phalaris minor* was significantly influenced by different herbicidal treatments. Metribuzine recorded lesser number of tillers in comparison with other treatments but metribuzine treatment found statistically at par with metribuzine + clodinafop propanyl.

Although B_1 and B_2 biotypes recorded numerically a greater number of leaves but statistically they were at par with each other. All biotypes showed the same number of leaves at harvest. Different herbicidal treatments were found to exert significant effects on the leaves' number of *P.minor*. Herbicide treatment of metribuzine reduced the leaf number per plant significantly as compared to other treatments.

Maximum numbers of leaves were recorded by control treatment. Metribuzine resulted in maximum loss of leaves, followed by the application of metribuzine + clodinafop propanyl which in turn, exerted significantly more effects than rest of other treatments. B_1 and B_2 biotypes recorded more panicles than other biotypes and they both are statically at par with each other. Highest panicle number were obtained in weedy check was compared with that of the different herbicidal treatment, herbicides were found to exert inhibitory effect on the panicle development and they reduced the number of panicles significantly. Least number of panicles was recorded in herbicide treatment of metribuzine as compared to other treatments.

Maximum DM accumulation was recorded in biotype B_2 which was significantly higher than other biotypes. Least amount of DM was found in biotype B_5. Similar results were recorded during both years, 2018-19 and 2019-20. Although all herbicidal treatments resulted in DM reduction of all bio types significantly as compared to weedy check. It was also observed that the herbicidal treatments of metribuzine + clodinafop propanyl, and metribuzine exerted more significant effect in reducing DM accumulation with respect to other treatments. All biotypes of *P.minor* produced significantly lower dry matter production with the application of metribuzine + clodinafop propanyl and metribuzine, but both treatments were statistically at par with each other in exerting their effects.

Conclusion

First date of sowing (1st November) was found significantly better than other date of sowing during both the years of study in terms of wheat grain yield and wheat control efficiency. Weed control treatment also showed the significant effect on the grain yield. From different weed control treatments, sulfosulfuron + metsulfuron 30 g/ha found significantly higher grain yield (49.55 q/ha and 47.12 q/ha) during 2018-19 and 2019-20. Higher weed control efficiency and grain yield was observed in bi-directional sowing method as compared to conventional methods. Bi-directional sowing resulted maximum grain yield (47.62 q/ha and 50.46 q/ha) during both year. Biotypes, B2 and B1 showed more resistance to different herbicides. Herbicidal treatments of metribuzin + clodinofop propanyl 54 g/ha and metribuzin 175 g/ha were found to be non-resistance to different biotypes.

References

Abbas, G., Ali, M. A., Abbas, G., Azam, M., & Hussain, I. (2009).Impact of planting methods on wheat grain yield and yield contributing parameters. *Journal of Animal. Plant Science*, 19(1), 30-33.

Abbas, T., Nadeem, M. A., Tanveer, A., & Ahmad, R. (2016).Evaluation of fenoxaprop-p-ethyl resistant little seed canary grass (*Phalaris minor*) in Pakistan. *Planta Daninha*, 34(4), 833- 838.

Abbas, T., Nadeem, M. A., Tanveer, A., Ali, H. H., & Farooq, N. (2018).Role of allelopathic crop mulches and reduced doses of tank-mixed herbicides in managing herbicide-resistant *Phalaris minor* in wheat. *Crop Protection*, 110(41), 245-250.

Abbas, T., Nadeem, M. A., Tanveer, A., Ali, H. H., & Matloob, A. (2017).Evaluation and management of acetyl-CoA carboxylase inhibitor resistant seed canary grass (*Phalaris minor*) in Pakistan. *Archives of Agronomy and Soil Science*, 63(11), 1613-1622.

Akdamar M, Tayyar S, Gokkus A. (2012). Effects of different sowing times on yield and yield related traits in bread wheat grown in Canakkale. Akdeniz University Agriculture Faculty Digest 15(2), 81-87.

Ali, S., Zamir, M. S. I. I., Farid, M., Farooq, M. A., Rizwan, M., Ahmad, R., &Hannan, F. (2016). Growth and yield response of wheat (*Triticum aestivum* L.) to tillage and row spacing in maize-wheat cropping system in semi-arid region. *Eurasian Journal of Soil Science, 5*(1), 53-61.

Ahmad, K., Shah, Z., Khan, I., Khan, M., & Khan, M. Q. (1993).Effect of post-emergence herbicides application and hand weeding on wheat and weed pressure. *Pakistan Journal Weed Science Research*, *6*(1-2), 40-45.

Amare, T. (2014).Effect of weed management methods on weeds and wheat (*Triticum aestivum* L.) yield. *African Journal of Agricultural Research*, 9(24), 1914-1920.

Arif, M., Tahir, M. J., Akram, M., Aslam, M., & Chaudhry, T. (1997).Effect of seed rates and drilling techniques on wheat yield. *Journal of Agricultural Research (Pakistan)*,35(5),303-308.

Arnold, R.N., M.W. Murray, E.J. Gregory and D. Smeal, (1988). Effects of herbicides on weeds in field corn grown on coarse-textured soils. *Jornal. Applied Agric. Research*., 3(1), 121-123.

Ashrafi, Z. Y., Mashhadi, H. R., Sadeghi, S., & Blackshaw, R. E. (2009). Study effects of planting methods and tank mixed herbicides on weeds controlling and wheat yield. *Journal of Agricultural Science*, 1(1), 101.

Aslam, M., Hussain, M., Akhtar, M., Cheema, M. S., & Ali, L. (2003). Response of wheat varieties to sowing dates. *Journal of Agronomy*. 4(2), 190-194.

Ayub, M., Nadeem, M. A., Tanveer, A., Tahir, M., Saqib, M. T. Y., & Nawaz, R. (2008).Effect of different sowing methods and times on the growth and yield of fennel (*Foeniculum vulgare* Mill.). *Pakiastan. Journal of Botony*, 40(1), 259-264.

Balyan RS & Malik RK (2000).New herbicides for Jungali Palak (*Rumex retroflexus* L.). *Indian Journal of Weed Science* 32(1/2), 86-88.

Balyan, R. S. (2001). Evaluation of new herbicides against mixed weed flora in wheat. *Indian Journal of Weed Science*, 33(3&4), 104-106.

Balyan, R. S., Yadav, A., Pahwa, S. K., & Malik, R. K. (1999). Response of fenoxaprop and other herbicides on isoproturon resistant and susceptible biotypes of little seed canary grass and other weeds in wheat. *Indian Journal of Weed Science*, 31(1&2), 38-43.

Banga, R. S., Yadav, A., & Malik, R. K. (2003).Bioefficacy of flufenacet and sulfosulfuron alone and in combination against weed flora in wheat. *Indian Journal of Weed Science*, 35(3&4), 179-182.

Beckie HJ (2006). Herbicide resistant weeds: Management tactics and practices. *Weed Technology* 20(3), 793-814.

Bhan, V. M., & Kumar, S. (1997). Integrated management of *Phalaris minor* in rice–wheat ecosystems in India. In Proceedings of International Conference on Ecological Agriculture: Towards Sustainable Development Place,. 2, 15-17.

Bhan, V.M., R.S. Pawar and R.K. Malik, (1982). Studies on Cultural Practices for Weed Management in Wheat. In Abstract of Papers, Annual Conference of India Society of Weed Science. Department of Agronomy, Haryana University, Hissar, India.

Bharat, R., Kachroo, D., Sharma, R., Gupta, M., & Sharma, A. K. (2012).Effect of different herbicides on weed growth and yield performance of wheat. *Indian Journal of Weed Science*, 44(2), 106-109.

Bilalis, D., Papastylianou, P., Konstantas, A., Patsiali, S., Karkanis, A., &Efthimiadou, A. (2010).Weed-suppressive effects of maize–legume intercropping in organic farming. *International Journal of Pest Management*, *56*(2), 173-181.

Bilalis, D., Sidiras, N., Economou, G., &Vakali, C. (2003).Effect of different levels of wheat straw soil surface coverage on weed flora in Viciafaba crops. *Journal of Agronomy and Crop Science*, *189*(4), 233-241.

Black CA. (1965). Methods of Soil Analysis Part-I, American Society of Agronomy. Madison, Wisconsin, USA.

Brar, L. S., Walia, U. S., & Jand, S. (2002). Characterization of isoproturon resistant Phalaris minor biotypes exposed to alternate herbicides under cropped and uncropped situations. *Indian Journal of Weed Science*, *34*(3&4), 161-164.

Brar, A. S., & Walia, U. S. (2007). Studies on composition of weed flora of wheat (*Triticum aestivum* L.) in relation to different tillage practices under rice-wheat cropping system. *Indian Journal of Weed Science*, 39(3&4), 190-196.

Brar, A. S., & Walia, U. S. (2008).Effect of rice residue management techniques and herbicides on nutrient uptake by Phalaris minor Retz.and wheat (*Triticum aestivum* L.). *Indian Journal of Weed Science*, 40(3&4), 121-127.

Brar, A. S., & Walia, U. S. (2009). Weed dynamics and wheat (*Triticum aestivum* L.) productivity as influenced by planting techniques and weed control practices. *Indian Journal of Weed Science*, 41(3&4), 161-166.

Brar, A. S., & Walia, U. S. (2010). Rice residue position and load in conjunction with weed control treatments-Interference with growth and development of *Phalaris minor* Retz. and wheat (*Triticum aestivum* L.). *Indian Journal of Weed Science*, 42(3&4), 163-167.

Brar, A. S., Sharma, P., Kahlon, C. S., & Walia, U. S. (2019).Available plant nutrients in soil as influenced by planting methods and herbicidal treatments. *Open Agriculture*, 4(1), 346-353.

Brar, L. S., Walia, U. S., & Dhaliwal, B. K. (1999).Bioefficacy of new herbicides for the control of resistant Phalaris minor in wheat. *Pesticide Research Journal*, 11(2), 177-180.

Cassman, K. G., Dobermann, A., Walters, D. T., & Yang, H. (2003). Meeting cereal demand while protecting natural resources and improving environmental quality. *Annual Review of Environment and Resources*, 28(1), 315-358.

Central agriculture university farm magazine (2018) ISSN:2279-0454,VOL18,NO,01

Chahal, P. S., Brar, H. S., & Walia, U. S. (2003). Management of Phalaris minor in wheat through integrated approach. *Indian Journal of Weed Science*, 35(1&2), 1-5.

Chaudhary, S. U., Hussain, M., Ali, M. A., & Iqbal, J. (2008).Effect of weed competition period on yield and yield components of wheat. *Journal*. *Agricultural Research*, *46*(1), 47-54.

Cheema, Z.A., and Farooq, M., (2007).Agriculture in Pakistan. Agriculture in Pakistan: Problems of small farmers and their solutions. 23 p. Allied Book Center, Urdu Bazar, Lahore, Pakistan.

Chester, LF. (1993). In: Proc.lnt. Symp.on Integrated Weed Management. Indian Soc. Weed Sci., Hisar vol.1, 5-15.

Chhipa, K. G., Pareek, R. G., & Jain, N. K. (2005).Evaluation of metsulfuron-methyl and sulfosulfuron alone and in combination with other herbicides against weed in wheat. *Haryana Journal of Agronomy*, 21(1), 72-73.

Chhokar RS and Malik RK (1999).Effect of temperature on the germination of Phalaris minor Retz. *Indian Journal of Weed Science* 31(2),73-74.

Chhokar, R. S., Sharma, R. K., Jat, G. R., Pundir, A. K., & Gathala, M. K. (2007). Effect of tillage and herbicides on weeds and productivity of wheat under rice–wheat growing system. *Crop Protection*, *26*(11), 1689-1696.

Chhokar RS and Sharma RK (2008). Multiple herbicide resistance in little seed canary grass (*Phalaris minor*): A threat to wheat production in India. *Weed Biology and Management* 8(2), 112-123.

Chhokar RS, RK Sharma and Indu Sharma. (2012). Weed management strategies in wheat: A review. *Journal of Wheat Research*. 4(2), 1-21

Chhokar RS, Sharma RK, Chauhan DS and Mongia AD (2006). Evaluation of herbicides against *Phalaris minor* in wheat in north-western Indian plains. *Weed Research* 46(1), 40-49.

Chhokar, R. S., Sharma, R. K., & Sharma, I. (2012). Weed management strategies in wheat-A review. *Journal of Wheat Research*, 4(2),1-21.

Chhokar, R. S., Sharma, R. K., Chauhan, D. S., &Mongia, A. D. (2006). Evaluation of herbicides against *Phalaris minor* in wheat in north- western Indian plains. *Weed Research*, 46(1), 40-49.

Chopra, R.K., Chopra, P.S (2005). Effect of herbicidal mixture on weeds and productivity in zero-tillage wheat under rice wheat growing system. Directorate of Wheat Research, 132 001.Haryana , India

Das, T. K., &Yaduraju, N. T. (2011). Effects of missing-row sowing supplemented with row spacing and nitrogen on weed competition and growth and yield of wheat. *Crop and Pasture Science*, 62(1), 48-57.

Devi, S., Hooda, V. S., Singh, J., & Kumar, A. (2017).Effect of planting techniques and weed control treatments on growth and yield of wheat. *Journal of Applied and Natural Science*, 9(3), 1534-1539.

Devi, S., Singh, J., Kamboj, N. K., &Hooda, V. S. (2017). Weed studies and productivity of wheat under various planting techniques and weed management practices. *International Journal Curr. Microbiol. Applied. Science*, 6(12), 3279-3289.

Dhaliwal, B. K., Walia, U. S., & Brar, L. S. (1998).Response of *Phalaris minor* Retz.biotypes to various herbicides. *Indian Journal of Weed Science*, 30(3&4), 116-120.

Dhawan R S, Punia S S, Singh S, Yadav D and Malik R K (2009). Productivity of wheat (*Triticum aestivum*) as affected by continuous use of new low dose herbicides for management of little seed canary grass (*Phalaris minor*). *Indian Journal Agronomy,* 54(1), 58-62.

Donaldson, E., Schillinger, W. F., & Dofing, S. M. (2001). Straw production and grain yield relationships in winter wheat. *Crop Science*, 41(1), 100-106.

Duary, B., &Yaduraju, N. T. (2006).Effect of sowing date, seed rate of wheat and different densities of little seed canary grass (*Phalaris minor* Retz.) on growth and productivity of wheat. *Journal of Crop and Weed*, 1(1), 5-8.

Eastridge, M. L., Bucholtz, H. F., Slater, A. L., & Hall, C. S. (1998). Nutrient requirements for dairy cattle of the National Research Council versus some commonly used ration software. *Journal of Dairy Science*, 81(11), 3049-3062.

Ejeta, G. (2010). African Green Revolution needn't be a mirage. *Science*, 327(5967), 831-832.

El-Samie, A., Megawer, E. A., Mekdad, A. A. A., & Mohamed, S. M. (2018). Effect of inter row spacing with or without weed control in wheat (*Triticum aestivum* L.). *Egyptian Journal of Agronomy*, 40 (The15th International Conference on Crop Science), 41-48.

Ercoli, L., & Masoni, A. (1995).Effects of row spacing and orientation on yield and yield components of winter wheat. *Science* 4(2) 215-221.

Ewers, R. M., Scharlemann, J. P., Balmford, A., & Green, R. E. (2009). Do increases in agricultural yield spare land for nature?. *Global Change Biology*, 15(7), 1716-1726.

Fahad, S., Hussain, S., Chauhan, B. S., Saud, S., Wu, C., Hassan, S. & Huang, J. (2015). Weed growth and crop yield loss in wheat as influenced by row spacing and weed emergence times. *Crop Protection*, 71(3), 101-108.

Farooq, O., & Cheema, Z. A. (2014). Influence of sowing dates and planting methods on weed dynamics in wheat crop. *Pakistan Journal of Agricultural Sciences*, 51(4), 817-825.

Farooq, S., Shahid, M., Khan, M. B., Hussain, M., & Farooq, M. (2015). Improving the productivity of bread wheat by good management practices under terminal drought. *Journal ofAgronomyandCropScience*,201(3),173-188.

Finch, J., Finch, J. V., & Mason, J. (2003).Negotiating family responsibilities.Routledge.

Fonts, J.R.M., De Souza, M.A., Cardosa, A.A., Cruz, C.D. and De Souza, M.A. (1997) Effect of spacing and sowing rate on yield and other agronomic characteristics of wheat (*Triticum aestivum* L.). *Revista Ceres* 4(3)4, 249-262.

Ford, S. A., & Babb, E. M. (1989).Farmer sources and uses of information. Agribusiness, 5(5), 465-476.

Gaurav, Verma, S.K., Meena, R.S., Maurya, A.C. and Kumar, S. (2018). Nutrients uptake and available nutrients status in soil as influenced by sowing methods and herbicides in kharif maize (Zea mays L.).*International Journal Agriculture Environment Biotechnology*. 11(1), 17-24.

Gebbers, R., &Adamchuk, V. I. (2010). Precision agriculture and food security. Science, 327(5967), 828-831.

Ghafari, S. R., Dass, A., Hamayoun, H., Mangal, M. Q., &Omran, A. H. (2017).Effect of row spacing on different wheat (*Triticum aestivum* L.) varieties in semi-arid region of Kandahar. *International Journal of Applied Research*, 3(7), 93-97.

Ghaffar, A., Mahmood, A., Yasir, A., Muhammad, N., Mahmood, T., Munir, M. K., & Sattar, A. (2013).Optimizing seed rate and row spacing for different wheat cultivars. *Crop Environment*, *4*(1), 11-18.

Gliessman, S. (2013). Agroecology: Growing the roots of resistance. *Agroecology and Sustainable Food Systems*, 37(1), 19-31

Glover, J. D. (2005). The necessity and possibility of perennial grain production systems. *Renewable Agriculture and Food Systems*, 20(1), 1-4.

Glover, J. D., Cox, C. M., &Reganold, J. P. (2007). Future farming: a return to roots?. *Scientific American*, 297(2), 82-89.

Glover, J. D., Culman, S. W., DuPont, S. T., Broussard, W., Young, L., Mangan, M. E., ... & Ferris, H. (2010). Harvested perennial grasslands provide ecological benchmarks for agricultural sustainability. *Agriculture, Ecosystems & Environment*, 137(1-2), 3-12.

Gomiero, T., Pimentel, D., &Paoletti, M. G. (2011). Is there a need for a more sustainable agriculture?.*Critical Reviews in Plant Sciences,* 30(1-2), 6-23.

Gopinath, K. A., Kumar, N., Pande, H., & Bisht, J. K. (2007). Bio-Efficacy of herbicides in wheat under zero and conventional tillage systems. *Indian Journal of Weed Science, 39*(3&4), 201-204.

Green, R. E., Cornell, S. J., Scharlemann, J. P., & Balmford, A. (2005).Farming and the fate of wild nature.science, 307(5709), 550-555.

Gupta, R., Gopal, R., Jat, M. L., Jat, R. K., Sidhu, H. S., Minhas, P. S., & Malik, R. K. (2010). *Wheat productivity in indo-gangetic plains of India during 2010: Terminal Heat Effects and Mitigation Strategies*. Report No. CIS-6150, CIMMYT.

Gussak, D., & Cohen-Liebman, M. S. (2001). Investigation vs. intervention: Forensic art therapy and art therapy in forensic settings. *American Journal of Art Therapy*, 40(2), 123.

Gomiero, T., Pimentel, D., & Paoletti, M. G. (2011). Is there a need for a more sustainable agriculture?. *Critical Reviews in Plant Sciences*, *30*(1-2), 6-23.

H. S. Gill & L. S. Brar (2009) Chemical Control of Phalaris minor and Avena ludoviciana in Wheat, *Pans*, 23,3, 293-296, DOI: 10.1080/09670877709412454

Halford, C., A.S. Hamill, J. Zhang and C. Doucet, 2001. Critical period of weed control in no-till soybean (*Glycine max*) and corn (*Zea mays*). *Weed Technol*ogy, 15(4), 737-744.

Hesammi, E. (2011). Different densities of weeds and wild oats (*Avena ludoviciana*) and canary grass (*Phalaris minor*) on yield and yield components of wheat cultivar Chamran. *Advance. Environment. Biology*, 5(8), 2497-2500.

Hussain, I., Khan, E. A., Hassan, G., Gul, J., Ozturk, M., Alharby, H., ...&Alamri, S. (2017). Integration of high seeding densities and criss cross row planting pattern suppresses weeds and increases grain yield of spring wheat. *Journal of Environmental Biology*, 38(5), 1139-1145.

Hussain, I., Khan, M. A., & Ahmad, K. (2003). Effect of row spacing on the grain yield and the yield components of wheat (*Triticum aestivum* L.).*Pakistan Journal of Agronomy* (Pakistan).,2(3),153-159.

Hussain, I., Sohail, M., Tanveer, S. K., &Muneer, M. (2018). Impact of planting density and growth habit of genotypes on wheat yield under raised bed planting method. *Science*, 37(3), 158-162.

Hussain, M., Mehmood, Z., Khan, M. B., Farooq, S., Dong-Jin, L., & Farooq, M. (2012). Narrow row spacing ensures higher productivity of low tillering wheat cultivars. *International Journal of Agriculture and Biology*, *14*(3),413-418.

Idnani, L. K., & Ashok, K. (2012). Relative efficiency of different irrigation schedules for conventional, ridge and raised bed seeding of wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, 57(2), 148-151.

Ishag, H. M., & Mohamed, B. A. (1996). Phasic development of spring wheat and stability of yield and its components in hot environments. *Field Crops Research*, *46*(1-3), 169-176.

Jackson, L., Bawa, K., Pascual, U., & Perrings, C. (2005). Agrobiodiversity: a new science agenda for biodiversity in support of sustainable agroecosystems. DIVERSITAS report, 4, 40.

Jain, N., Mishra, J. S., Kewat, M. L., & Jain, V. (2007). Effect of tillage and herbicides on grain yield and nutrient uptake by wheat (*Triticum aestivum*) and weeds. *Indian Journal of Agronomy*, 52(2), 131-134.

Jalis, A., 1987. Weed problems in wheat. Progressive Farming, 7, 20-30.

Jat, L. K., Singh, S. K., Latare, A. M., Singh, R. S., & Patel, C. B. (2013). Effect of dates of sowing and fertilizer on growth and yield of wheat (*Triticum aestivum*) in an Inceptisol of Varanasi. *Indian Journal of Agronomy*, 58(4), 611-614.

Jat, M. L., Gupta, R., Saharawat, Y. S., & Khosla, R. (2011). Layering precision land leveling and furrow irrigated raised bed planting: Productivity and input use efficiency of irrigated bread wheat in Indo-Gangetic Plains. *American Journal of Plant Sciences*, 2(4), 578-588.

Jat, R. K., Punia, S. S., & Malik, R. K. (2007).Efficacy of herbicide mixtures and sequential applications against different weeds in wheat (*Triticum aestivum* L.). *Indian Journal of Weed Science*, 39(1&2), 132-134.

Jat, R. S., Nepalia, V., & Chaudhary, P. D. (2003). Influence of herbicides and methods of sowing on weed dynamics in wheat (*Triticum aestivum* L.). *Indian Journal of Weed Science*, 35(1&2), 18-20.

Kahloon, M. H., Iqbal, M. F., Farooq, M., Ali, L., Fiaz, M., & Ahmad, I. (2012). A comparison of conservation technologies and traditional techniques for sowing of wheat. *Journal Animal Plant Science.* 22(3), 827-830.

Kamboj, N. K., Hooda, V. S., Gupta, G., Devi, S., & Jinger, D. Performance of wheat under different planting methods and weed management practices, *Ann. Agric. Res. New Series*,38(1), 31-37.

Kappler, B. F., Lyon, D. J., Stahlman, P. W., Miller, S. D., & Eskridge, K. M. (2002). Wheat Plant Density Influences Jointed Goatgrass (Aegilops cylindrica) Competitiveness. *Weed Technology*, 16(1), 102-108.

Kaur, T., Bhullar, M. S., & Kaur, S. (2019). Control of herbicide resistant Phalaris minor by pyroxasulfone in wheat. *Indian Journal of Weed Science*, 51(2), 123-128.

Kaur, J., Singh, G., & Singh, A. (2014). Competitiveness of wheat (*Triticum aestivum* L.) cultivars under spacing and weed levels. *Indian Journal of Ecology*, 41(2), 357-359.

Keil, A., D'souza, A., & McDonald, A. (2015). Zero-tillage as a pathway for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: does it work in farmers' fields?. *Food Security*, *7*(5), 983-1001.

Kolar, J. S., & Mehra, S. P. (1992). Changing scenario of weed flora in agroecosystems of Punjab. *Changing Scenario of Weed Flora in Agroecosystems of Punjab.*, 25(2),252-262.

Korres, N. E., & Froud‐Williams, R. J. (2002). Effects of winter wheat cultivars and seed rate on the biological characteristics of naturally occurring weed flora. *Weed Research*, *42*(6), 417-428.

Kristensen, L., Olsen, J., & Weiner, J. (2008). Crop density, sowing pattern, and nitrogen fertilization effects on weed suppression and yield in spring wheat. *Weed Science*, 56(1), 97-102.

Kumar, A., Malik, R. K., Sirohi, R. M., & Hasija, R. C. (2006). Performance of new herbicides at two doses and spray volumes against resistant *Phalaris minor* in Wheat at Faers' Fields. *Annals of Biology*, 22(2), 161.

Kumar, N. (2016). Physiological and biochemical characterization of isoproturon resistance in *Phalaris minor* and its management (Doctoral dissertation, GB Pant University of Agriculture and Technology, Pantnagar-263145 (Uttarakhand)).

Kumar, S., Malik, R. K., & Singh, R. C. (2003).Effect of sulfosulfuron on density and dry weight of weeds under varied irrigations in wheat. *Indian Journal of Weed Science*, 35(1&2), 10-14.

Kurchania, S. P., Tiwari, j. P., Patel, M. L., & Jain, H. C. (1993). Effect of chemical weed-control under different sowing dates and planting patterns on growth and sink potential of dwarf wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences*, 63(9), 591-593.

Kabir, M. S., Salam, M. U., Chowdhury, A., Rahman, N. M. F., Iftekharuddaula, K. M., Rahman, M. S., ...& Islam, A. S. (2015). Rice vision for Bangladesh: 2050 and beyond. *Bangladesh Rice Journal*, *19*(2), 1-18.

Lampkin, L. M., & Boris, E. T. (2002). Nonprofit organization data: What we have and what we need. *American Behavioral Scientist*, 45(11), 1675-1715.

Lockeretz, W. (Ed.). (2007). *Organic farming: an international history*. CABI.

Lowenberg-DeBoer, J. (1996). Precision farming and the new information technology: Implications for farm management, policy, and research: *Discussion. American Journal of Agricultural Economics*, 78(5), 1281-1284.

Mahajan, G., & Brar, L. S. (2001). Integrated management of Phalaris minor in wheat. *Indian Journal of Weed Science*, 33(1&2), 9-13.

Mahajan, G., & Brar, L. S. (2002). Integrated management of Phalaris minor in wheat: rationale and approaches–a review. *Agricultural Reviews*, *23*(4), 241-251.

Mahajan, G., Sardana, V., Sharma, N., & Chauhan, B. S. (2018). Grain quality of dry- seeded rice in response to sowing dates and genotypes. *International Journal of Plant Production*, 12(2), 95-106.

Majeed, A., Muhmood, A., Niaz, A., Javid, S., Ahmad, Z. A., Shah, S. S. H., & Shah, A. H. (2015). Bed planting of wheat (*Triticum aestivum* L.) improves nitrogen use efficiency and grain yield compared to flat planting. *The Crop Journal*, 3(2), 118-124.

Malekian, B., Ghadiri, H., Kazemeini, S. A., & Edalat, M. (2013). Efficacy evaluation of sulfosulfuron, metsulfuron-methyl plus sulfosulfuron, mesosulfuron-methyl plus iodosulfuron-methyl and iodosulfuron plus mesosulfuron herbicides in winter wheat (*Triticum aestivum* L.). *Journal Biology Environment Science*, 7(21), 177-182.

Mali, H., & Choudhary, J. (2013). Performance of bread wheat (*Triticum aestivum* L.) varieties under different row spacing. *Journal of Wheat Research*, 4(2), 55-57.

Malik, R. K., & Singh, S. (1993). Evolving strategies for herbicide use in wheat: resistance and integrated weed management. In Proc. Indian Soc. Weed Sci. Int. Symp. Hisar, India (Vol. 1, pp. 225-238).

Malik, R. S., Yadav, A., Malik, R. K., & Singh, S. (2005). Efficacy of clodinafop, fenoxaprop, sulfosulfuron and triasulfuron alone and as tank mixture against weeds in wheat. *Indian Journal of Weed Science*, 37 (3&4), 180-183.

Marwat, K. B., Khan, M. A., Hashim, S., Nawab, K. H. A. L. I. D., & Khattak, A. M. (2011). Integrated weed management in wheat. *Pakistan. Journal Botony*, 43(1), 625-633.

Meena, B. L., & Singh, R. K. (2013). Response of wheat (*Triticum aestivum*) to rice (*Oryza sativa*) residue and weed management practices. *Indian Journal of Agronomy*, 58(4), 521-524.

Meena, R. S., & Singh, M. K. (2011). Weed management in late-sown zero-till wheat (*Triticum aestivum*) with varying seed rate. *Indian Journal of Agronomy*, 56(2), 127-132.

Mishra, J. S., Singh, V. P., & Jain, N. (2010). Long-term effect of tillage and weed control on weed dynamics, soil properties and yield of wheat in rice-wheat system. *Indian Journal of Weed Science*, 42 (1&2), 9-13.

Mollah, M. I. U., Bhuiya, M. S. U., Hossain, M. S., & Hossain, S. M. A. (2015).Growth of Wheat (*Triticum aestivum* L.) under raised bed planting method in rice-wheat cropping system. *Bangladesh Rice Journal*, *19*(2), 47-56.

Muñoz-Romero, V., Benítez-Vega, J., López-Bellido, R. J., Fontán, J. M., & López-Bellido, L. (2010).Effect of tillage system on the root growth of spring wheat. *Plant and Soil*, 326(1-2), 97-107.

Nanher, A. H., & Raghuvir, S. (2015). Effects of weed control treatments on wheat crop and associated weeds. *Advance Research Journal of Crop Improvement*, 6(2), 158-165.

Naresh, R.K., S. Tomar, S. Purushottam, S.P. Singh, D. Kumar, B. Pratap, V.A. Kumar & H. Nanher (2013) Testing and evaluation of planting methods on wheat grain yield and yield contributing parameters in the irrigated agro-ecosystem of western Uttar Pradesh, India. *African Journal Agricultural Research*, 9(1), 176-182

NesterovA, O. A., & Chukanova, O. V. (1981). The harmfulness of the predominant weed species in wheat. *Sibirskiĭ Vestnik Sel'skokhozyaĭstvennoĭ Nauki*, (5), 9-13.

Nicholls, C. I., Altieri, M. A., Dezanet, A., Lana, M., Feistauer, D., & Ouriques, M. (2004).A rapid, farmer-friendly agroecological method to estimate soil quality and crop health in vineyard systems. *Biodynamics*, 7(1),33-39.

Noorka, I. R., & Tabasum, S. (2013). Performance of raised beds and conventional planting method for wheat (*Triticum Aestivum* L.)Cultivation in Punjab, Pakistan.In Sustainable Food Security in the Era of Local and Global Environmental Change (pp. 321-335).Springer, Dordrecht.

Olsen, S. R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (No. 939). US Department of Agriculture.

Olsen, J., Kristensen, L., & Weiner, J. (2005). Effects of density and spatial pattern of winter wheat on suppression of different weed species. *Weed Science*, 53(5), 690-694.

Osman, E. A. M., Swelam, A. A., Manal, A. H., & Sheren, N. N. (2015). Effect of raised bed planting technology on productivity, macro nutrients uptake of bread wheat and saving irrigation water. *Fayoum Journal of Agricultural Research and Development*, 30(1), 49-62.

Pandey, I. B., & Dwivedi, D. K. (2007).Effect of planting pattern and weed-control methods on weed growth and performance of wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, 52(3), 235-238.

Pandey, I. B., & Kumar, K. (2005).Response of wheat (*Triticum aestivum*) to seeding methods and weed management. *Indian Journal of Agronomy*, 50(1), 48-51.

Paoletti, M. G., Gomiero, T., & Pimentel, D. (2011). Introduction to the special issue: towards a more sustainable agriculture. *Critical Reviews in Plant Sciences*, 30(1-2), 2-5.

Pathania, R., Prasad, R., Rana, R. S., Mishra, S., & Sharma, S. (2018).Growth and yield of wheat as influenced by dates of sowing and varieties in north western Himalayas. *Journal of Pharmacognosy and Phytochemistry*, 7(6), 517-520.

Perfecto, I., & Vandermeer, J. (2010).The agroecological matrix as alternative to the land-sparing/agriculture intensification model. *Proceedings of the National Academy of Sciences*, 107(13), 5786-5791.

Pretty, J. (2008). Agricultural sustainability: concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491), 447-465.

Phour, M., & Sindhu, S. S. (2018). Bioherbicidal potential of rhizosphere bacteria for management of Phalaris minor weed. *Research on Crops*, *19*(3), 380-386.

imentel, D. (2010). The Effects of the Resistance of Antibiotics and Pesticides on US Public Health.Institute of Medicine, National Academy of Sciences.

Prasad, S. (2017).Effect of sowing time and nutrient management on growth and yield of heat tolerant varieties of wheat (Doctoral dissertation, JNKVV, Jabalpur).

Pretty, J. N., & OBE, J. P. (2002). *Agri-culture: Reconnecting people, land, and nature*. Routledge.

Pretty, J. (Ed.). (2005). Towards a More Sustainable Agriculture,*The Pesticide Detox*. Earthscan, London. 1-84407-142-1

Pretty, J. (2008). Agricultural sustainability: concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1491), 447-465.

Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005).The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research*, 15(5), 319-337.

Prinsa*, Hem C. Joshi, Babita Joshi and S.K. Guru (2019) management of isoproturon-resistant *Phalaris minor* in wheat by alternate herbicides under tarai region conditions *Journal of Agricultural Science and Food Research* Volume 10, Issue 3

Punia, S. S., Singh, S., & Yadav, D. (2011). Bioefficacy of imazethapyr and chlorimuron-ethyl in clusterbean and their residual effect on succeeding rabi crops. *Indian Journal of Weed Science*, 43(1&2), 48-53.

Punia, S. S., Yadav, D. B., Kaur, M., & Sindhu, V. K. (2017).Post-emergence herbicides for the control of resistant seed canary grass in wheat. *Indian Journal of Weed Science*, 49(1), 15-19.

Ramadas, S., Kumar, T. K., & Singh, G. P. (2019). Wheat production in India: Trends and prospects. *Recent Adv. Grain Crop. Res.*

Rasool, R., Bhullar, M. S., Singh, M., & Gill, G. S. (2019). Flufenacet controls multiple herbicide resistant *Phalaris minor* Retz. in wheat. *Crop Protection*, 121(2), 127-131.

Reddy, K. N. (2001).Effects of cereal and legume cover crop residues on weeds, yield, and net return in soybean (*Glycine max*) 1. *Weed Technology*, 15(4), 660-668.

Roy, S., Das, T. K., & Singh, S. B. (2006). Persistence of clodinafop in soil, wheat crop and *Phalaris minor*. *Pesticide Research Journal*, 18(1), 87-91.

Saini, M. K., & Walia, U. S. (2010).Effect of planting patterns and weed control treatments on *Phalaris minor* growth and productivity of wheat (*Triticum aestivum*). *Indian Journal of Agronomy*, *55*(2), 110-113.

Salam, M. A., Alam, M. K., & Rashid, M. H. (2013).Effects of different tillage practices and cropping patterns on soil physical properties and crop productivity. *Journal of Tropical Resources and Sustainable Sciences*, 1(1), 51-61.

Sardana, V., Walia, U. S., & Mahajan, G. (2001).Management of broadleaf weeds in wheat (*Triticum aestivum* L.). *Indian Journal of Weed Science*, 33(1and2), 69-71.

Shaban, S.A., Soliman, S., Yehia, Z.R. and El-Attar, M.H. (2009). Weed competition effect on some (*Triticum aestivum*) quality and quantity components. *Egypt, Journal Agro*nomy 31(2), 135-147.

Shah, W. A., Bakht, J., Ullah, T., Khan, A. W., Zubair, M., & Khakwani, A. A. (2006). Effect of sowing dates on the yield and yield components of different wheat varieties. *Journal of Agronomy*,1(5), 106-110.

Shahzad, K., Bakht, J., Shah, W. A., Shafi, M., & Jabeen, N. (2002). Yield and yield components of various wheat cultivars as affected by different sowing dates. *Asian Journal of Plant Sciences*. 1(5), 522-525..

Sharif, M., Jan, A., Khan, A., Sattar, A., Bughti, M. K., & Anjum, J. (2019). 63. Effect of wheat planting density and weed management on nutrient accumulation and uptake of wheat and weeds under agro-climatic condition of Quetta-Pakistan. *Pure and Applied Biology* (PAB), 8(2), 1641-1654.

Sharma, S. N., & Kumar Singh, R. (2011). Seed rate and weed management on yield and nutrient uptake of wheat (*Triticum aestivum*). *Indian Journal of Agricultural Sciences*, 81(12), 1174.

Sial, M. A., Arain, M. A., Javed, M. A., & Nizamani, N. A. (2001).Response of wheat genotypes on yield and yield components with changing plant population densities. *Pakistan Journal of Botony*, 33, 797-800.

Siddiqui, S.S. and R.A. Shad, (1991). Interference of various densities of Indian sweet clover *Melilotus indica* Linn.in wheat. *Pakistan Journal of Weed Science Society*, 4(2), 69-75.

Singh RD and Ghosh AK (1982). Soil profile distribution and effect of temperature and soil depth on germination of *Phalaris minor* Retz. In: Abstract, Annual Conference of Indian Society of Weed Science. Hissar, India: *Indian Society of Weed Science*. pp. 41-42.

Singh S, Malik RK, Balyan RS and Singh S (1995).Distribution of weed flora of wheat in Haryana. *Indian Journal of Weed Science* 27(3&4),114-121.

Singh, A. K., Kumar, R. A. K. E. S. H., Singh, A. K., & Kumari, A. N. U. P. M. A. (2011). Bio-efficacy of sulfosulfuron on weed flora and irrigated wheat (*Triticum aestivum* L.) yield. *Environment and Ecology*, 29(2A), 834-838.

Singh, A. P., Kolhe, S. S., Bhamri, M. C., Purohit, K. K., & Chaudhary, T. (2008). Yield of rice-wheat cropping system as influenced by chemical and mechanical weed management in Chhattisgarh. *Indian Journal of Weed Science*, 40(1&2), 26-28.

Singh, A., Singh, Y., Singh, R., Upadhyay, P. K., Kumar, R., & Singh, R. K. (2019).Effect of cultivars and weed management practices on weeds, productivity and profitability in zero-till direct-seeded rice (*Oryza sativa*).*Indian Journal of Agricultural Sciences*, 89(2), 353-9.

Singh, B., A.K. Dhaka, R.K. Pannu and S. Kumar: (2013).Integrated weed management. A strategy for sustainable wheat production.Agric.Rev., 34(4), 243-255

Singh, G. and O.P. Singh (1996): Response of late-sown wheat (*Triticum aestivum*) to seeding methods and weed-control measures in flood-prone areas. *Indian Journal of Agronomy,* 41(2), 237-41.

Singh, G., Singh, M., & Singh, V. P. (2002). Effect of metsulfuronmethyl alone and in combination with 2, 4-D and surfactant on non-grassy weeds and wheat yield. *Indian Journal of Weed Science*, 34(3&4), 175-177.

Singh, G., Singh, O. P., Singh, S., & Prasad, K. (2010). Weed management in late sown wheat (*Triticum aestivum*) after rice (*Oryza sativa*) in rice-wheat system in rainfed lowland. *Indian Journal of Agronomy*, 55(2), 83-88.

Singh, K., & Kundra, H. C. (2003). Bio-efficacy of herbicides against isoproturon resistant biotypes of Phalaris minor in wheat. *Indian Journal of Weed Science,* 35(1&2), 15-17.

Singh, K., & Sharma, R. (2019).Effect of different methods of sowing and row orientation on growth, yield and quality of wheat (*Triticum aestivum* L.). *Agricultural Science Digest-A Research Journal,* 39(1), 51-54.

Singh, M. K., Mishra, A., Khanal, N., & Prasad, S. K. (2019).Effects of sowing dates and mulching on growth and yield of wheat and weeds (*Phalaris minor* Retz.). *Bangladesh Journal of Botany*, 48(1), 75-84.

Singh, R. P., Verma, S. K., & Kumar, S. (2017). Crop establishment methods and weed management practices affects crop growth, yield, nutrients uptake and weed dynamics in wheat. *International Journal of Bio-resource and Stress Management,* 8(3), 393-400.

Singh, S. (2007). Role of management practices on control of isoproturon-resistant little seed canarygrass (*Phalaris minor*) in India. *Weed Technology*, *21*(2), 339-346.

Singh, S., Singh, K., Punia, S. S., Yadav, A., & Dhawan, R. S. (2011). Effect of stage of *Phalaris minor* on the efficacy of accord plus (Fenoxaprop+ metsulfuron, readymix). *Indian Journal Weed Science*, 43(1&2), 23-31.

Singh, S. P., Yadav, R. S., Godara, S. L., & Kumawat, A. (2017).Efficiency of herbicides in groundnut (Arachis hypogaea) under hot arid conditions of Rajasthan. *Indian Journal of Agronomy*, 62(2), 201-205.

Smit, J. J., & Cairns, A. L. P. (2000). Resistance of little seeded canary grass (*Phalaris minor* Retz.) to ACC-ase inhibitors. *South African Journal of Plant and Soil*, 17(3), 124-127.

Spink, J.H., Semere, T., Sparkes, D.L., Whaley, J.M., Foulkers, M.J., Clare, R.W. and Scott, R.K.(2000). Effect of sowing date on plant density of winter wheat. *Annals of Applied Biology*, 137(2), 179-188.

Subbiah BV and Asija GL. (1956). A rapid procedure for the determination of available N in soils. *Current Science* 25(4), 259-260

Swelem, A. A., Hassan, M. A., & Osman, E. A. M. (2015).Effect of raised bed width and nitrogen fertilizer level on productivity and nutritional status of bread wheat. *Egypt. Journal Applied Science* 30(3), 223-234.

Tahir, M., Ali, A., Nadeem, M. A., Hussain, A., & Khalid, F. (2009). Effect of different sowing dates on growth and yield of wheat (*Triticum aestivum* L.) varieties in district Jhang, Pakistan. *Pakistan journal of life and social sciences*, 7(1), 66-69.

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011).Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences*, 108(50), 20260-20264.

Tiwari, AN. (1990). Final Technical Report. All India Coordinated Research Programme on Weed Control (Oct. I985-March 1990) Centre Gujrat, Kanpur, India: Chandra Shekhar Azad Uni. of Agriculture & Technology. Verma.H.N. and Srivastava, v.e. (1989). *Indian Journal Agronomy* 34,170-79.

Tomar, SS., jain, P.C. and paradkar,N.R.(2004).effect of post emergent herbicide on weed control in wheat (*Triticum aestivum*). National symposium on resource conservation and agriculture productivity Ludhiana, Punjab pp.216-217.

Trewavas, A. J. (2001). The population/biodiversity paradox.Agricultural efficiency to save wilderness. *Plant Physiology*, 125(1), 174-179.

Tripathi, S. C., & Das, A. (2017). Bed planting for resource conservation, diversification and sustainability of wheat based cropping system. *Journal of Wheat Research*, 9(1), 1-11.

Upasani RR, Prasad K. Puran AN. (2008).Effect of promising herbicides on weed control efficiency and yield of wheat. *Indian Journal of Weed Science*. 40(1 -2), 109 -110.

Varshney, S., Hayat, S., Alyemeni, M. N., & Ahmad, A. (2012). Effects of herbicide applications in wheat fields: is phytohormones application a remedy. *Plant Signaling & Behavior*, *7*(5), 570-575.

Verma, S. K., Singh, S. B., Sharma, R., Rai, O. P., & Singh, G. (2008).Effect of cultivars and herbicides on grain yield and nutrient uptake by wheat (*Triticum aestivum*) and weeds under zero-tillage system. *Indian Journal of Agricultural Science*, 78(11), 984-987.

Verma, S. K., Singh, S. B., Singh, G., & Rai, O. P. (2007).Performance of varieties and herbicides on production potential of wheat (*Triticum aestivum* L.) and associated weeds. *Indian Journal of Weed Science*, 39(3&4), 230-233.

Walia, U. S. & Gill, H. S. (2008).Interaction between herbicide and nitrogen in the control of *p.minor* in wheat. Tropical Pest Management 31:266-.DOI:10.1080/09670878509370988

Walia, U. S., Brar, L. S., & Dhaliwal, B. K. (1997).Resistance to isoproturon in *Phalaris minor* Retz.in Punjab. *Plant Protection Quarterly*, 12(1), 138-140.

Walia, U. S., Kaur, T., Nayyar, S., & Singh, K. (2010). Performance of carfentrazone-ethyl 20%+ sulfosulfuron 25% WDG–a formulated herbicide for total weed control in wheat. *Indian Journal of Weed Science*, 42(3&4), 155-158.

Walia, U. S., Brar, L. S., & Jand, S. (2003). Integrated effect of planting methods and herbicides on Phalaris minor and wheat. *Indian Journal of Weed Science, 35*(3&4), 169-17

Walia, U.S., L.S. Brar and B. Singh. (2006). Recommendations for weed control in field crops. Research Bulletin, Punjab Agricultural University Ludhiana, 1-32.

Wall, P. C. (2017).3 Conservation Agriculture: Growing More with Less–the Future of Sustainable Intensification. Conservation Agriculture For Africa, 30.

Mollah, M. I. U., Bhuiya, M. S. U., Hossain, M. S., & Hossain, S. M. A. (2015).Growth of Wheat (Triticumaestivum L.) under Raised Bed Planting Method in Rice-Wheat Cropping System. *Bangladesh Rice Journal*, *19*(2), 47-56.

Walkley A and Black CA. (1934). Estimation of organic carbon by chromic acid titration method. *Soil Science* 37, 29-38

Williams, D. L., & Dollisso, A. D. (1998). Rationale for research on including sustainable agriculture in the high school agricultural education curriculum. *Journal of Agricultural Education*, 39, 51-56.

Yadav DB, Yadav A, Punia SS and Chauhan BS. (2016). Management of herbicide-resistant *Phalaris minor* in wheat by sequential or tank-mix applications of pre- and post- emergence herbicides in north-western Indo-Gangetic plains. *Crop Protection.* 89(2), 239-247

Yadav, R. S., & Dahama, A. K. (2003). Effect of planting date, irrigation and weed-control method on yield and water-use efficiency of cumin (*Cuminum cyminum*). *Indian Journal of Agricultural Science*, 73(9), 494-496.

Zameer Ahmed Kalwar, Amanullah Tunio, Muhammad Yousif Shaikh, Imran Khan, Jatoi, Qamaruddin Jogi. (2018) Impact of sowing dates on the growth and yield of wheat variety benazir-2013, Sindh Province, *Pakistan. Int. Journal Agronomy. Agricultural Reearch.* 12(5), 65-71,.

Zand, E., Baghestani, M. A., Soufizadeh, S., Eskandari, A., PourAzar, R., Veysi, M., ...& Barjasteh, A. (2007). Evaluation of some newly registered herbicides for weed control in wheat (*Triticum aestivum* L.) in *Iran. Crop Protection*, 26(9), 1349-1358.

Zipoli, G., & Grifont, D. (1994). Panicle contribution to bidirectional reflectance factors of a wheat canopy. *Remote Sensing*, 15(16), 3309-3313.

APPENDIX-I

ANOVA grain yield experiment first during 2018-2019 and 2019-20

2018-19					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	50.205			
Factor A	2	311.701	155.850	63.169	0.00094
Error(a)	4	9.869	2.467		
Factor B	4	1,529.621	382.405	38.224	0.00000
Interaction A X B	8	319.151	39.894	3.988	0.00396
Error(b)	24	240.105	10.004		
Total	44	2,460.651			

2019-20					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**significance**
Replication	2	96.641			
Factor A	2	472.323	236.161	42.044	0.00206
Error(a)	4	22.468	5.617		
Factor B	4	1,034.016	258.504	33.320	0.00000
Interaction A X B	8	452.448	56.556	7.290	0.00007
Error(b)	24	186.195	7.758		
Total	44	2,264.090			

APPENDIX-II

ANOVA grain yield experiment second during 2018-2019 and 2019-20

2018-19					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**significance**
Replication	2	6.608			
Factor A	3	532.532	177.511	54.803	0.00009
Error(a)	6	19.434	3.239		
Factor B	4	1,995.149	498.787	223.275	0.00000
Interaction A X B	12	59.989	4.999	2.238	0.03436
Error(b)	32	71.487	2.234		
Total	59	2,685.199			

2019-20					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**significance**
Replication	2	83.710			
Factor A	3	504.132	168.044	23.903	0.00098
Error(a)	6	42.181	7.030		
Factor B	4	2,057.139	514.285	236.793	0.00000
Interaction A X B	12	68.598	5.716	2.632	0.01435
Error(b)	32	69.500	2.172		
Total	59	2,825.25			

APPENDIX-III

Cost of cultivation

S.N.o	Particulate	Cost Rs/ha
1	Field preparation	5000
2	Seed	4500
3	Sowing	2500
4	Fertilizers	1590
5	Herbicides	875
6	Hand weeding (where herbicides not applied)	8000
7	Irrigation	2000
8	Pesticides	1875
9	Harvesting	3750
10	Miscellaneous	2000
Total (where weed control done with Herbicides)		**24090**
Total (where weed control done with Hand weeding)		**32090**

APPENDIX IV

Detailed of biotypes

S.N.o	Particulate	Location
1	**Biotype B_1**	**Haryana**
2	**Biotype B_2**	**Haryana**
3	**Biotype B_3**	**Punjab**
4	**Biotype B_4**	**Punjab**
5	**Biotype B_5**	**Punjab**