Impact of crop geometry on growth and yield of maize

(*Zea mays* L.) in Punjab alluvial soils

Thesis

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By

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LOVELY PROFESSIONAL UNIVERSITY

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CERTIFICATE

This is to certify that thesis entitled **"Impact of crop geometry on growth and yield of (*Zea mays L*) maize in Punjab alluvial Soils"** submitted in partial fulfillment of the requirement for the degree of **"Master of Science in Agriculture (Agronomy)''** of Lovely professional university, Phagwara, Punjab is a record of a bonafide research work carried out by **Mr. Zate Gajanan Sheshrao Reg No.(11210358)** under my guidance and supervision.

Place: Phagwara, Punjab.

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the thesis entitled **"Impact of crop geometry on growth and yield of (*Zea mays L*) maize in Punjab alluvial Soils"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis /publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Phagwara, Punjab (**Mr. Zate Gajanan Sheshrao)**

Date: **/ / 2014** Regrastation No.11210358

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LIST OF ABBREVIATIONS

DAS	- days after sowing
CGR	- crop growth rate
AGR	- absolute growth rate
NAR	- net assimilation rate
LAI	- leaf area index
NPK	- nitrogen, phosphorus, potassium
cm	- centimeter
g/plant	- gram per plant
kg/ha	- kilogram per hectare
g/cob	- gram per cob
q/ha	- quintals per hectare
g	- gram
g/plant/day	- gram per plant per day
@	- at the rate
CD at 5%	- critical difference at 5%probability
SE (m) ±	- Standard error of mean
et al.	- et alia (and his associates)
%	- percent
ha^{-1}	-per hectare
$plant^{-1}$	- per plant
No. / no.	– number
cob^{-1}	- pre cob
viz	- namely

ABSTRACT

A field experiment was conducted at Lovely Professional University Phagwara Punjab to study "Impact of crop geometry on growth and yield of maize (*Zea mays*) in Punjab alluvial soils" during *Rabi* 2013. The experiment was laid out in Randomized Complete Block Design (RCBD), with three replications, constituting 6 treatment *viz.*, six various spacing, (based on the plant population per unit area), 60cm x 20cm (83,333 plant ha^{-1}), 30cm x 30cm square planting (1,11,111 plant ha^{-1}) ,skip row planting *i.e.*, plant 2 row and skip 1 row design (77,777 plant ha^{-1}), 60cm x 30cm (55,555 plant ha^{-1}), 30cm x 15cm(2,22,222 plant ha^{-1}), 60cm x 10cm (1,66,666 plant ha^{-1}.

The results indicate that, crop geometry comprises, higher plant population ha^{-1},(30cm x 15cm) recorded higher plant height, leaf area $plant^{-1}$, LAI as well as, number of green leaves per plant as compared to recommended spacing (60cm x 20cm) and low plant population density (60cm x 30cm) which recorded higher dry matter production $plant^{-1}$.The higher density caused larger angular leaves formation per plant to compete intense intra-competition throughout life cycle. Moreover wider spacing dry matter production per plant in ease due to less challenging, environment of lesser planting.

Low plant population density (60cm x 30cm), recorded higher, no. of cobs $plant^{-1}$, weight of cob^{-1} with and without husk, 1000 grains weight, cob length and grain weight $plant^{-1}$,harvest index and nutrient uptake as well as nutrient available after harvest as compared to dense planting (30cm x 15cm)., Interestingly, recommended spacing (60cm x 20cm), of maize crop recorded significant grain yield (58.11 q ha^{-1}).,than, medium high and high plant population density ha^{-1}. The results clearly shown that optimum planting geometry exponentially increases the availability of nutrients and other factors which resulted in increased grain yield or commercial produce.

1. INTRODUCTION

India is the world's second largest producer of cereals. The total area under cereals cultivation has been increased from 97.32 Million ha (2004-05) to 104 Million ha (2011-12) respectively the production of cereals was increased 185.78 to 226.58 million tonnes. (Sekhar *et.al.,* 2012) The important cereals in India are wheat, paddy, maize, sorghum and barley.

Maize (*Zea mays L.*) is one of most important cereal crop of the world. it ranks third after wheat and rice it most important crop in word.

It is considered important staple food crop of the world and also known as 'Queen of cereals' because of its high productivity potential and adoptability to survive wide range of environmental condition at also acquired a dominant role in the farming sector it grown under temperature 21^0 c to 32^0 c. and remain as most versatile crop in nature. In the world it accounts for 8 per cent and 25 per cent in area and production respectively. It contributes about 20 per cent of the world's total cereal production. Maize is classified in to different group of types based on its endosperm namely flour corn, pop corn, dent corn, flint corn, sweet corn, waxy corn, pod corn and triped maize recently among the various purpose of corn baby corn is grown as a vegetable purpose and the grain of special variety called 'pop corn' characterized by a hard corneous interior structure which considering as the favorite food for children in urban areas dent corn has remained predominant because of its utility for various purposes.

In India maize is widely cultivated as rainfed crop during kharif but it can be grown successfully during *rabi* and summer season under irrigation. Over 85 per cent of maize produced in India is consumed as human food (Gangaiah, 2008). Green cob are roasted and consumed by people with great interest. it has important place in Indian economy, like rice, wheat and millets crop, maize especially use for human food it also used for feeding cattle, poultry and industries for the production of starch, alcohol, syrup, lactic acid, acetic acid etc. it is warm weather loving crop and can be successfully grown in a area receiving an annual rainfall of 60 cm, with well distribution throughout its growing period.

In India maize is grown over an average of 10.6 million hectares with a production of 21.76 million tonnes with average productivity is 2.51 tonnes ha^{-1} (Yadav *et.al.,* 2013). Punjab holds key position as important cereal crops growing state in India. In Punjab, it is cultivated in an area of 1.29 lakh hectares with production of 4.71 million tonnes and productivity of 36.50 q/ha hectares (National conference pusa new Delhi 2013).

Maize crop management practices involve decision making on several cultural practices aimed to maximize grain yield, like crop geometry and plant population (Bhonde, 2013). Establishment of optimum plant population is essential to get maximum grain yield. There have been many studies to determine the optimum plant density for maize crop. The cultural practices coupled with the crop geometry, optimum plant population and spacing between row and plant play vital role in enhancing the productivity increment of maize (Agasibagil, 2006).

Crop geometry is one of the important factors, which has to be maintained at optimum level to harvest maximum solar radiation and it turn better photosynthate formation and utilization the soil resources effectively (Thavaprakaash and. Velayudham, 2002) it helps maintaining optimum plant population by avoiding excessive crowd and thereby enabling cereals to utilize the resources and maintained micro climate in the cropping area. (Mohammad *et.al*., 2012). Proper adjustment of plants over the field not only helps maintaining the optimum plant population but also enables the optimum utilization of land, light and other input resources uniformly and efficiently. So it is imperative to develop such a spacing pattern which may help avoiding dense planting and supporting the maize to utilize these resources more effectively and efficiently towards higher production.

Crop geometry and plant population play and important role in competitive balance between Stover and grain yield if the plant density was increased grain yield was increased but the Stover yield was decreased (Jitendra *et.al.,* 2004)

Management of corn crop geometry and plant population has been used to increased corn productivity (Mahapatra *et.al.,* 2006) recorded yield increase up to 10 percent with reducing row spacing and increase 8 percent photosyntheticaly active radiation at silking (Lusis *et al*., (2002)

It has been reported dense population results in weak barren plants and results in lesser grain formation (Bangarwal *et.al.,* 1997). Increasing plant population per unit area beyond a certain limit results in intense inter and intra competition among the plants for sunlight, nutrients moisture and may cause severe crop lodging. Though the spacing requirement of grain and fodder maize has been standardized, the information on the influence of crop geometry on yield and quality of maize hybrid under intercropping situation is lacking m (Thavaprakaash and Velayuham,2002) Information on the optimum crop geometry to explore the available resources, suitable intercrops for higher income per unit area. (Thavaprakaash and Velayudham, 2007)

Taking into consideration the above aspects, to find out suitable crop geometry and optimum plant densities for alluvial soil of Punjab, a field experiment was conducted at Lovely Professional University Phagwara Punjab (District Kapurthala) in 2013-14 *rabi* Season with the following objectives:

1. To study the impact of crop geometry on growth parameters of maize.
2. To evaluate the optimum spacing for maximum yield production of maize.
3. To study the effect of crop geometry on nutrient uptake by maize.

2. REVIEW OF LITERATURE

2.1 Effect on growth and growth components

2.1.1 Plant height

Agasibagil (2006) conducted field experiment at Dharwad (Karnataka) on crop and reported that plant height, number of functional leaves, and dry matter accumulation were significantly higher at (45cm x 20cm) and (60cm x 30cm) spacing during the growth period as compared to (45cm x 30cm) and (60cm x 15cm). The effect of spacing on growth and development of maize. It was found that the spacing of 45 cm x 20 cm recorded the maximum plant height of 176.2 cm, which was significantly superior to wider row spacing of 60 cm x 15 cm.

Hussein F and Abouziena (2008) conducted field In a experiment at Sharkia, Egypt, during kharif season maize Abouziena reported the plant height of 268 cm at crop geometry of 60 x 25 cm spacing followed by 70 x 30 spacing (243 cm) Also it has been resulted if row spacing was increased respectively the plant height was shorter.

Lyocks *et al.* (2013) during field experiment at Nigeria (2009-10), and found, that row spacing was increased significantly with increase in plant height. Maximum plant height of 158.8 cm was recorded at row spacing of (75cm x 25cm) which was significantly higher than narrow spacing (40cm x 20cm) (119.3 cm).

2.1.2 Number of green leaves and leaf area index

Kole (2010) emphasized that reducing the spacing maize crop between plant to plant by 20 cm or 10 cm, increases the size of individual plants in terms of leaf size, number of leaves, total leaf area, It was also found number of green leaves per plant (10.92), and leaf area index (20.58) were significantly higher in spacing of 45 cm × 10 cm compared to spacing (45cm x 20cm).

Maddonni (2001) Conduct field experiment at Argentina and reported if row spacing was increased significantly detected on leaf dimensions, individual leaf area, plant leaf area and narrow short leaves, Small plant leaf leaves, erectophile leaf habit were promoted by the increased plant population .

Agasibagil (2006) conducted field experiment and reported plant grown with (60x30cm) spacing he found having more green leaves (14) and leaf area index in at 60 DAS. It was significantly superior as compared to (60x20cm) spacing and stated if plant spacing was reduced respectively the number of green leaves was decreased also Further, it was observed that the spacing of (60cm x 15cm) recorded the maximum leaf area index of 4.90

which was significantly superior over (45cm x 30cm narrow 45cm x 15cm) spacing in maize crop.

Eman *et al*. (1999) reported that increasing plant population density upto 11.11 plants m^{-2} in SC 108 increased leaf area index (LAI) and number of leaves per plant throughout the growing season. However, in SC 301 and SC 604 increasing plant population density from 8.33 to 11.11 plants m^{-2} did not increase leaf area index significantly.

Muhammad *et al*. (2004) studied the effect of three different plant spacing and four phosphorus level under irrigated condition during kharif 2001 and 2002 seasons Plant spacing of (60cm x 30cm) apart attained maximum plant height (176 cm) compared to spacing (60cm x 20cm) (169cm) moreover spacing (60x30 cm) living maximum green leaf (13) and earlier maturity (durations 94 DAS). in 60x20cm spacing days of maturity 98 it was increased.

Thavaprakaash et *al*. (2005) field experiment was conducted during late Rabi 2002 and 2003 seasons. Including two factors viz. crop geometry and intercropping system. While irrespective of the treatments Green cob yields were higher (68.01 to 77.07 q/ha) during late rabi 2002 season as compared to 2003 (5167 to 56.08 q/ha) respectively improved fodder quality parameters viz. crude protein, crude fiber ether extract, mineral contain, recorded during the late rabi 2002 over 2003 season. During rabi 2002 in crop geometry level 60x19 was recorded maximum yield 79.76 q/ per ha.

Tony Bratsh *et al*. (2009) has found that for cultivar popcorn Virginia climate rarely allows for ideal on stalk drying specially given our repeated (60cm x 15cm) growers with limited production can hand harvest compared to (75cm x 30cm)

2.1.3 Stem girth (cm) per plant.

Toaima *et al*. (2001) found if plant population increase per ha^{-1} it resulted into thinner stem diameter because of high plant population per m^2 and competition for space, nutrient, and moisture.

Crowaer *et al*. (1967) conduct field experiment and observed if plant density increased from 40,000 to 80,000 plant ha^1 respectively stem diameter was decreased from 27 mm to 24 mm. It because of plant space and competition.

Camper and Gender (1973) recorded maximum stem diameter 18mm at 34600 plant ha^1 significantly also if plant population was increased from 34600 to 64200 ha^1 stem diameter was decreased from 18mm to 15mm.

Grosbach (2008) reported if row spacing increases from 15 inch to 30 inch a very little difference was found , in lower stalk diameter from 0.94 inch to 1.02 plant^{-1} and if row spacing was increased 30 cm to 60 cm significantly increased stalk diameter 1.3 inch plant^{-1}.

2.1.4 absolute growth rate (AGR)

Amanullah *et al*. (2010) conducted field experiment at Peshawar during summer and reported increased plant population from 4 plant per m^{-2} to 10 plant per m^{-2} result significantly decreased AGR (1.99 to 0.99 g/plant/day^{-1}), NAR (4.70 to 2.64 g/m^{-2}/day^{-1}), RGR (98.51 to 93.92 g m^{-2}/day^{-1}) and grain yield per plant (78.62 to 36.87 g/plant^{-1}).

2.1.5 Net assimilation rate (NAR)

Ishaque *et al*. (2010) reported that as plant density increased from 57142 plant ha^{-1} to 95238 plants ha^{-1} respectively the net assimilation rate decreased from 4.53 g m-2 day-1 to 3.79 g m-2 day-1 Low NAR at high plant density was attributed to proportionally less increase in DMA per unit area as compared to increase in leaf area duration and leaf area index per plant.

2.1.6 Crop growth rate (CGR)

Ocloo *et al*. (2011) reported that crop geometry (90x40cm) recorded high Crop growth rate (7.56 gm^{-2} d^{-1}) as compare to the another Crop geometry (45cm x 20cm) it obtained significantly lower crop growth rate (5.03 gm^{-2} d^{-1}).

Abeleke *et al*. (2013) reported row arrangement of maize crop significantly difference in the crop growth rate of maize crop (CGR) in 2005 and 2006 inter row crop produce more crop growth rate (12.1/g/m^{-2}/wk^{-1}) and (18.7/g/m^{-2}/wk^{-1}) as compared to intra row arrangement in both year (11.5/g/m^{-2}) and (15.7/g/m^{-2}/wk^{-1})

2.1.7 Days of Silking

Jithendra *et al*. (2013) reported that plant spacing increased from (60 cm x30 cm) to the (75 cm x30 cm) than days of silking decreased respectively 64 to the 55.15 and stated if row spacing was decreased significantly increased days of silking.

Abraha (2013) quoted that row spacing affected days of silking if row spacing increased significantly decreased days of 50 percent flowering at (220.25cm) row spacing recorded 64.66 days and 180 cm recorded 56.2 days silking respectively.

2.1.8 Total dry matter production

Kole (2010) reported if plant population increased ha^{-1} significantly decreased leaf dry weight, stem dry weight and cob dry weight because of high plant population plant compete to each other for nutrient space then low plant population per ha^{-1} and also found at 45cm x 10cm high leaf dry weight at 30,45, and at harvest (7.77,19.64,75.52 g $plant^{-1}$ as compared to spacing 45cm x 20cm obtained (6.87, 16.51,72.17 g $plant^{-1}$) respectively.

Agasibagil (2006) conduct field experiment and stated at 30 DAS lower population ha^{-1} (3.77 g plant-1) recorded significantly higher leaf dry weight as compared to higher plant population ha^{-1} (3.48 g $plant^{-1}$) at 60 DAS to at harvest increase plant population from lower to higher, ha^{-1} there is significant reduction in leaf dry weight.

Dalvi (1984) conduct field experiment at Dapoli (Maharashtra) and reported that the dry matter production was higher in narrow spacing (45 cm x 30 cm) 223.25 g $plant^{1}$) It was significantly higher as compare to wider spacing (60 cm x 15 cm) it was (166.47 g $plant^{1}$) and stated if plant to plant spacing was decrease then per plant dry matter was decrease respectively.

Ahmad *et al*. (2010) observed decrease in dry matter production per plant with increase in plant density, but if plant population was increased it result respectively increased dry matter per ha Crop planted at plant density 95238 plants produced significantly more dry matter (1329.12 g $m\text{-}^{2}$) against 1252.36 g m-2 and 1100.44 g $m\text{-}^{2}$ at plant density of 57142 and 40816 plants ha^{-1} respectively.

Ibeawuchi et *al*. (2008) conducted field experiments at the Teaching and Research Farm Federal University of Technology Owerri (Nigeria) and reported if plant spacing was increased from (25 cm x 75 cm) to (100cm x 100cm), it significantly had highest above ground biomass at taselling and silking stage.

2.2. Effect of crop geometry on yield of Maize

2.2.1 Number of cob per plant

Mahapatra *et al*. (2006) conducted a field experiment at Bhubaneswar and reported that the spacing of (60cm x 20cm) and (60cm x 30cm) significantly increased the number of cobs (1.7 and 1.9 $plant^{-1}$) respectively over the (45cm x 30cm) and (45cm x 20cm) spacing (1.5 and 1.6 $plant^{-1}$). Yield attributing characters of corn such as length of corn, number of cob plant^{-1}, cob weight with husk and cob weight without husk were significantly higher under wider spacing of 60 cmx20 cm as compared to closer spicing of (30cm x 20cm).

Mashiqa (2012) plant density significantly affect the number of cobs per plant in maize the number of cobs obtained were higher (2.3 plant^{-1}) at plant density 33,330 ha^{-1} (75cm x 40cm) it was higher as compared to other plant density 44,440 (75cm x 30cm) (2.0) cob per plant.

Zarapkar (2006) and Kunjir (2007) conducted two different a field experiment on sweet corn at Dapoli (Ratnagiri) Maharashtra and observed that length, girth, weight of cob and grains weight per cob (80g), number of grain rows, and 1000 grains weight increased significantly with wider spacing (75cm x 20cm) as compared to narrower spacing of (60cm x 20cm and 45cm x 20cm).

Zheng (2009) reported that total number of baby cob with (60x15cm)(1.7 plant^{-1}) among three harvests were highly significant while compared to (40cm x 15cm)(1.4 plant^{-1}) among the eight different locations no significance was observed.

2.2.2 Cob length

Kanakdurga *et al*. (2012) conducted field experiment during early *rabi* season of (2010-11) at Hyderabad to study the influence of planting methods, spacing on sweet corn and reported at 60cm x 20cm recorded high cob length (13.4 cm) as compared to 45cm x 15cm (12.9 cm) if row to row spacing was lower respectively the length of per cob will be lower and it also obtained low grain yield .

Thattil (1986) reported if maize inter row spacing was decreased respectively cob size, Cob length, and grain size was decreased at (25 cm x20 cm) spacing obtained low cob size and grain size as compared to other spacing (40 cm x 35cm).

Baloyi (2013) reported that higher cob diameter and cob length of maize at 10000 and 20000 plant ha^{-1} and) (row to row spacing 90 cm) as compared to 30000 and 40000 plant ha^{-1} and stated if plant population was higher per ha respectively the cob diameter was lower.

Power *et al*. (1974) conducted field experiment at northern plains in their studies on row spacing and relative maturity on dryland corn reported that crop spaced at 100 cm between rows produced bigger ears plant-^{1} as compared to crop spaced at 50 cm row spacing.

Fanadzo (2010) reported the effects of inter-row spacing (45cm and 90 cm) Cob length decreased from 39.9 to 37.2 cm when plant population was increased from 40000 to

60000 plants ha-^{1} and Cob length increased from 37.9 to 39.2 cm when inter row spacing was decreased from 90 to 45 cm.

2.2.3 Cob weight with husk and without husk

Kole (2010) conduct field experiment at Dharwad (Karnataka) reported that highest single cob weight with husk (45cm x 20cm) (17.2 g/cob) and (45cm x 10cm) (18.02 g/cob^{-1}) and same experiment weight of single cob without husk receded (45cm x 20cm) (8.80 g/cob^{-1}) and (45cm x 10cm) (7.40 g/plant) respectively.

Sikandar Azam *et* al. (2007) reported if plant to plant spacing was decreased from 45cm to 15cm then decreased the per cob weigh (293 g/cob^{-1}) to (263 g/cob^{-1}) but if plant to plant spacing was decreased 45cm to 15cm then the biomass ha^{-1} was decreased (15.204 q/ha-^{1}) to (15.306 q/ha^{-1}) respectively.

2.2.4 Number of grains per cob

Bangarwn and Sannjiev (1997) found that number of grain cob$^{–1}$ was decrease significantly if plant population was increased ha^{-1} and also decreased number of cob plant^{-1}.

Choudhary *et al*. (2014) revealed that maize is highly sensitive to low temperature and in winter maize due to low temperature slow the crop growth and lower yield.

2.2.5 Grain yield

Thavaprakaash and Velayudham (2013) conducted field experiment at eastern block farm Coimbatore (Tamil Nadu) study two different crop geometry and reported at spacing (60cm x 19cm) produces higher yield (9507 kg ha-1) it was higher as compared to spacing (45cm x 25cm) (8870 kg ha-1) and stated if row spacing was decreased decreases grain yield plant^{-1} and grain yield ha^{-1} respectively.

Sikandar *et al.* (2007) conducted a field experiment at Peshawar (Pakistan) and reported grain yield, thousand seed weight, and number of cob per plant was significantly higher at wider crop geometry (70 cm x 45cm) (29.97 q/ha^{-1}) than (70 cm x 15cm) and (70 cm x 25) (27.40 q/ha^{-1}) It stated if plant to plant spacing was decreased respectively the grain yield was decreased.

Koli (1971) in a field experiment at Kwadaso (Ghana) observed that (60 cm x 60 cm) 10,890 plant population per acre gave significantly higher yield of corn (20.7 q acre-^{1}) as compared to (30 cm x 15cm) (87120 plant per acre) and yield was 13.3 q acre^{-1} ultimately reported if spacing was increased and plant population was decreased respectively the yield was increased per acre.

Drew *et al*. (2009) analyzed various skip row planting trials in Nebraska Lincoln north Platte and reported if taken skip row planting it obtained higher grain yield (35 bu/acre.) then normal planting pattern (30 cm x 15cm) (75 bu/acre), So skip row planting result higher grain yield as compare to the normal spacing.

Schlegel (2004) field experiment was conduct skip row planting in K-state South west near Tribune and in row skip planting which obtained higher yield 100 bu/a acre it was significantly higher than plant 2 row and skip 1 row, or plant 2 and skip 2 row. If population was maintain 15,000 plant per acre higher yield as can be obtained compare to 20,000 plants per acre and stated if plant population was increased per acre it reduced grain yield per acre.

Ryan (2012) reported the grain yield were highest at the lowest planting densities (86,000 and 99,000 ha^{-1}) as 10.2 and 10.4 mg per ha respectively .If the planting density was increased 136,000 and 161,000 plant in ha^{-1} response to lowering grain yield per ha from 9.2 and 8.7 per ha respectively.

Nagy and Megyes (1999) Reported that 70,000 to 80,000 plants per ha is feasible to obtain optimum yield per ha under assured rainfall conditions however 60, 000 plants per ha was recommended under dry conditions to obtain feasible yield per ha.

Lusis *et.al*. (1994) conduct field experiment in Ames, Iowa, US, and reported if plant population was decreased 99000 pant ha^{-1} to 50000 ha^{-1} respectively decreased grain yield ha^{-1}.

2.2.6 Harvest index%

Abraha Lemlem (2013) reported highest harvest index in mono cropping (46%) as compared to inter cropping with cow pea significantly low harvest index (45%) similarly grain yield and dry biomass pre ha was also low in inter cropping (grain 23.81 q/ha^{-1}) (biomass 50.67 q/ha^{-1}) as compared mono cropping (grain 30.56 q/ha-^{1}) (biomass 65.51 q/ ha).

2.3. Effect of crop geometry on nutrient uptake by plant

Thavaprakaash & Velayudham (2007) studied two crop geometry level and two short intercropping with control taken in main plot during kharif 2002 season. They found higher uptake of N (180.42kg/ha) and P(23.4kg/ha) K(331.12 kg/ha) was record (45x25cm) spacing as compared to (60cm x 20cm) level. Respectively of treatment Green cob yield were higher (7243 to 8037 kg/ha) during kharif 2002 season respectively

Waghmode (2010) conducted field experiment at Dharwad and reported the available N,P,K in soil after harvest of maize in RDF found highest , (N,195.7.,P,18.67.,K,258.32 kg/ha^{-1}) and organic carbon 0.70% as compared to top dressing (N,167.,P,17.92.,K,248.8 kg/ha^{-1}) found lowest NPK and organic carbon 0.70% .

Velayudhan *et al*. (2013) conducted field experiment at Coimbatore and reported higher nutrient uptake at (60 cm x19 cm) crop geometry level N(190.2 kg ha^{-1}), P (24.5 kg ha^{-1}), K(375.5 kg ha^{-1}) it Significantly higher than the other crop geometry level (45 cm x 25 cm) it obtained ,N (183.9 kg ha^{-1}),P (22.8 kg ha^{-1}),K(364.2 kg ha^{-1}).

Dotaniya (2013) in pot culture experiment at Indian Institute of Soil Science Jabalpur reported, at maturity stage nutrient uptake by maize N (0.35 g plant^{-1}), P (0.09 g plant^{-1}), (0.65 g plant^{-1}) it was higher as compare to field experiment (60x20cm).

Agasibagil (2006) reported increase in plant density from low to high recorded significant decreased in nitrogen phosphorus and potassium uptake Result shown at 55,555 plant ha^{-1} uptake of N (178.1 kg ha^{-1}), P(39.0 kg ha^{-1}), K(163.8 kg ha^{-1}) was higher as compared to 1,11,111 plant density ha^{-1}.

Plenet and Lemaire (2000) reported N concentration of 100 g dry matter was 2.81 % and dry matter production in his study of determination of critical N concentration in maize crop.

Narayanappa *et.al.* (2003) Conducted field experiment at Bangalore and reported N concentration of davna crop if plant spacing increased 30 x 15 to 45 x 15 increased NPK concentration in plant sample at 45cm x 15cm,(2.75%),(0.58%), (2.52%) NPK, respectively as compared to 30cm x 15cm (2.70%),(0.56%),(2.58%) NPK, respectively.

Mallarino and Antonio (2011) study nutrient uptake by corn and soybean of P and K concentration in Corn Vegetative Tissue and it found 0.12 percent phosphorus and 1.23 percent potassium.

Arif F (2012) conducted field experiment at Iran and reported higher NPK concentration in plant sample (2.35, 0.41, 2.41% in 100 g dry matter) similarly available P in soil (12.1 kg ha) and k (229 kg ha).

Ozpinar (2009) conduct experiment at dardanos study three different tillage practices and obtained high nutrient uptake shallower rot tiller tillage(ST) (302 kg/ ha^{-1}) as compared to mouldboard plough (MP) (277 kg/ha^{-1}).

3. MATERIALS AND METHODS

The present investigation on “Impact of crop geometry on growth and yield of maize (*Zea mays* L.) in Punjab alluvial soils” was undertaken during *Rabi* season 2013 at the Main Agricultural Research Field, Lovely Professional University, Phagwara, (Punjab) under Irrigated conditions. The details of materials used and methodology adopted during the investigation are explained in details in this chapter.

The experiment was conducted in Randomized Completely Block Design (RCBD) with three replications at the experimental farm of Main Agricultural Research Field, LPU, Punjab. The plot size for each treatment was 4.8 m x 3.6 m. The recommended agronomic practices and plant protection measures were adopted to raise a healthy crop.

3.1 Experimental site and Location

The experiment was conducted at Main Agricultural Research Field, Lovely Professional University, Phagwara, Punjab near block no 34 located at 31^{o} 15’ N latitude, 75^{o} 41’ E longitude and at an altitude of 245 m above mean sea level (AMSL).

3.2 Soil and its characteristics of the experimental site

The experiment was laid out on sandy clayey loam soil. The composite soil sample was collected from experimental field from a depth of 0 to 30 cm before sowing and after harvest of crop sample was air dried, powdered and allowed to pass through 2 mm sieve and analyzed for various physical and chemical properties. The data of soil analysis along with the methods used are presented in Table 3.1.

3.3 Climatic conditions

The Main Agricultural field of Lovely Professional University is situated in the (PB-3) Central Zone of the State. This zone receives rainfall from both South-West and North-East monsoons which is well distributed from June to September with lower coefficient of variation. The monthly meteorological data of rainfall, temperature and relative humidity during the period of experimentation 2013-14 is given in Table 3.2.

The data on weather parameters such as rainfall (mm), mean maximum and minimum temperature (^{0}C) and relative humidity (%) recorded at Meteorological Observatory, Main Agricultural Research Station Amritsar, Punjab. during the experimental season and data represented in Table 3.2.

Table 3.1: Soil physical and chemical properties in experimental site.

Sr. No	Particulars	Values (0- 30 cm depth)	Method employed
I	**Physical properties**		
1	Coarse sand (%)	19%	International pipette method (Piper, 1966)
2	Fine sand (%)	42%	
3	Silt (%)	7%	
4	Clay (%)	32%	
II	**Chemical properties**		
1	Ph	7.96	Buckmoric Hmeter (Piper,1966)
2	Electrical conductivity (dS/m)	0.33	Jackson (1973)
3	Organic carbon (%)	0.48	Wet oxidation method (Jackson, 1973)
III	**Available nutrient status**		
1	Available N (kg/ha)	168.45	Micro Kjeldahl method (Jackson, 1973)
2	Available P (Kg/ha)	22.42	Olsen's method (Jackson,1973)
3	Available K (kg/ha)	325.23	Flame photometer method (Jackson, 1973)

3.4 Previous crop on the experimental site

During 2012 chili and cucumber was grown during *kharif* and *rabi* season at respectively. However at *kharif* 2013 there is no crop production was taken.

3.5 Experimental details

3.5.1 Details of the experimental Design and layout

The experiment was laid out in a Randomized Completely Block Design (RCBD) having 6 treatments which replicated thrice. The plan of layout of the experiment is given in Fig: 3.2

Table 3.2: Meteorological data monthly for the experimental year (*rabi* 2013-14)

Months	Rainfall (mm)	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)
	2013-14	**2013-14**	**2013-14**	**2013-14**
October	75.94	30.5	17	83
November	23.11	26.4	9.9	74.8
December	3.56	20.6	6.2	89.1
January	18.04	19.1	4.4	86.1
February	8.87	20.2	5.8	79.9
March	68.32	25.6	10.5	74.5
April	6.1	34.8	18.8	49.5
Total	203.94			

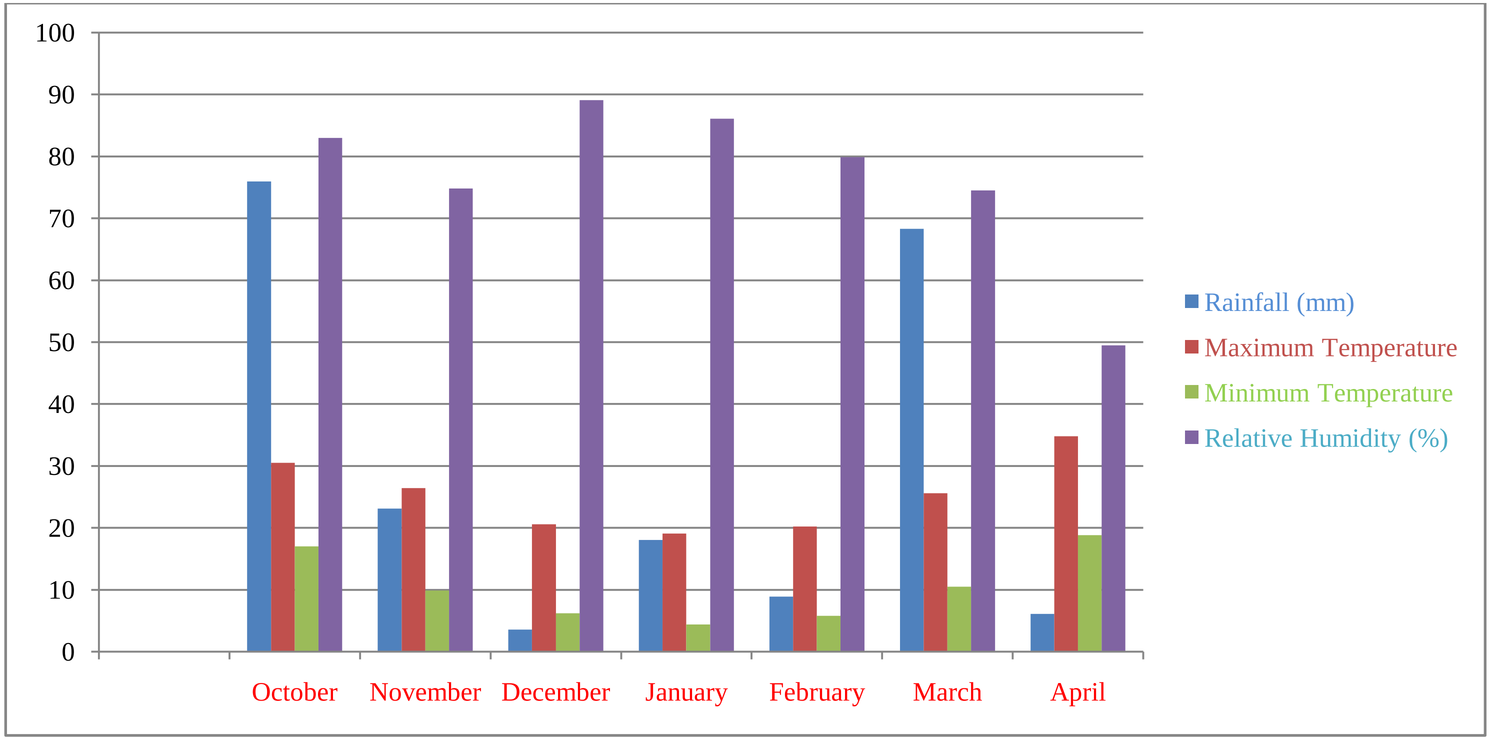

Fig: 3.1 Monthly metrological data *rabi* 2013-14.

Table 3.3: Details of the experimental Design and layout.

Sr No	Contents	Details
1	Design	RCBD
2	Replications	3
3	Treatment combinations	6
4	Total no of plot	18
5	Gross plot size	4.8m x 3.6 m
6	Net plot size	3 m × 3 m
7	Cultivar	31Y45 Hybrid

Table 3.4: Details of experimental treatments.

Treatment	Planting density (Plants ha^{-1})	Planting geometry (cm x cm)
T_1 recommended spacing	83,333	60 x 20
T_2 Square planting	1,11,111	30 x 30
T_3 Skip row planting	77,777	Plant 2 row followed by skip 1 row model
T_4 Low plant density	55,555	60 x 30
T_5 High plant density	2,22,222	30 x 15
T_6 Medium high plant density	1,66,666	60 x 10

3.6 Cultural operations

3.6.1 Land Preparation

The land was ploughed with the help of tractor by using mould board plough and discplough 2, times then cultivator was passed to crush the big clods and 1, harrowing to get the fine tilth. The land was levelled and the field was laid out in to experimental plots as per the plan and then bunds were formed to all the plots.

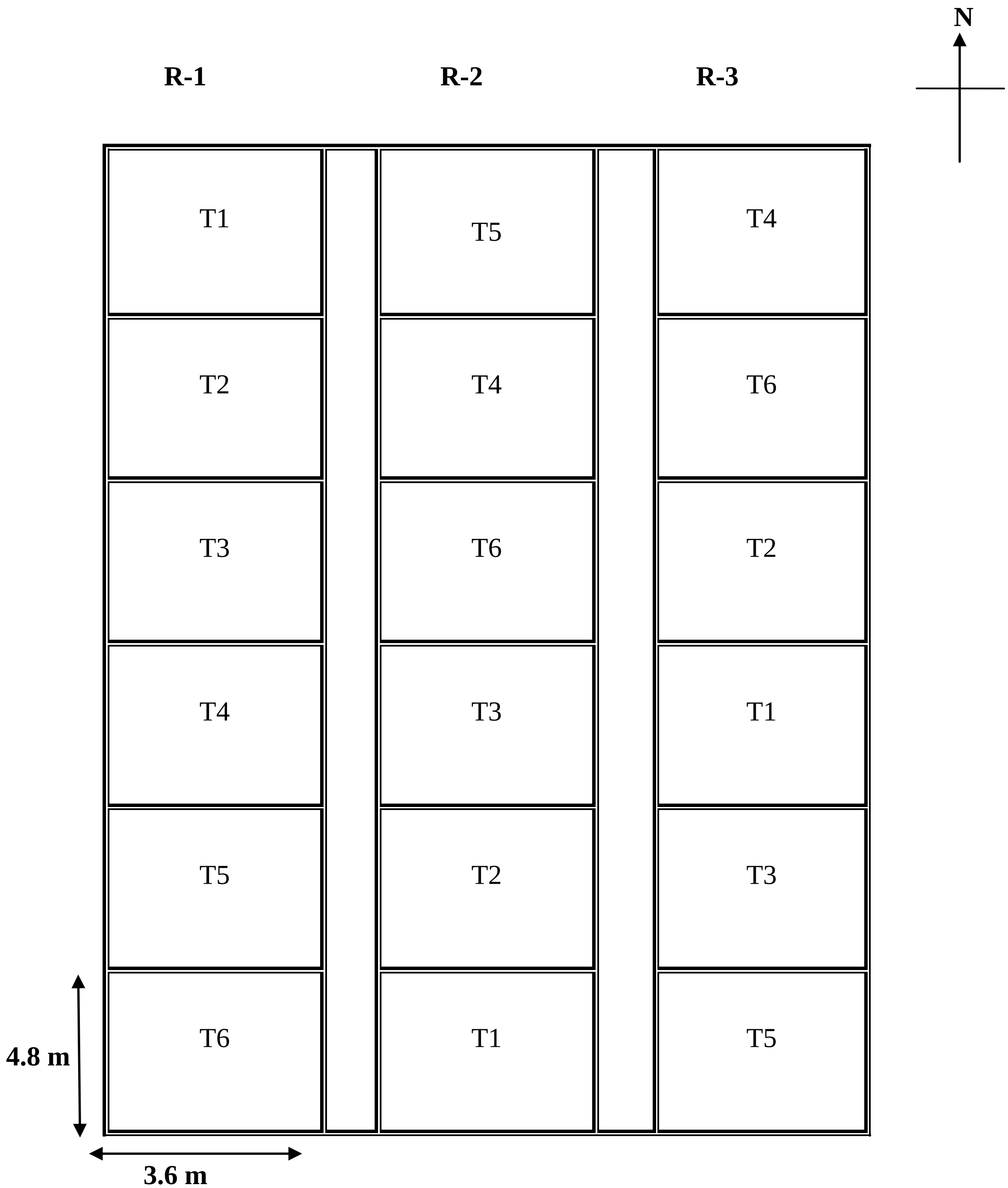

Fig 3.2: Plan of layout of experiment

Plate.3.1. General view of experimental plot (55 DAS)

3.6.2 Seed treatment

The maize seed was treated with thiram @ of 3 g kg^{-1} of seed before sowing in order to keep the seed free from soil pathogens.

3.6.3 Seeds and sowing

The furrows were opened given space as per treatment. In these furrows, 2-3 seeds were dibbled per hill at depth of 3-4 cm the sowing was taken on 22th October 2013 and covered with the soil. Hybrid of '31Y45' developed by 'Pioneer' were used for sowing with recommended seed rate of 25 -30 kg per ha.

3.6.4 Gap filling and thinning

Gap filling was taken up 10 DAS after sowing to maintain optimum plant population and thinning was carried out 15 DAS after sowing to remove excessive plant growth.

3.6.5 Hand weeding

Experimental land was kept weeds free throughout the experiment by manual weeding at interval of 15 Days.

3.6.6 Earthing up

Earthing up was done at 28 DAS after the top dressing with nitrogenous fertilizer.

3.6.7 Fertilizer application

Recommended dose of N, P and K (120:60:40 kg N, P2O5 and K2O ha-1) were applied to the soil. Full dose of 'P' and 'K' were applied along with 50 % of N to maize crop at the same time of sowing. The remaining 50 % N applied in two splits at one after 35 DAS Top dressing before 1st irrigation and second dose before silking.

The fertilizer used were urea (46% N), Di ammonium phosphate 18% and 46 % P_2O_5) mutate of potash (60% K_2O) for N, P_2O_5 and K_2O, respectively.

3.6.8 Irrigation

Three irrigation were given to different times of intervals first irrigation was applied 15 DAS second irrigation 45 DAS and last irrigation was applied 75 DAS.

3.7 Collection of experimental observations

3.7.1 Maize growth parameters

In order to assess the effect of different treatments on the growth and yield of the crop, periodical observations were recorded from each net plot five plants these were randomly selected and observations on growth was recorded periodically 30,45, 60,75, 150 DAS and at harvest.

3.7.1.1 Plant height (cm)

The plant height of five randomly selected tagged plants in each plot was measured from base of the plant to the base of the fully opened top leaf until tassel emergence. Later, the plant height was measured from the base of the plant to the collar of flag leaf and expressed in (cm).

3.7.1.2 Number of green leaves per plant

The number of green and functional leaves per plant was recorded by counting the fully opened green leaves of randomly selected five tagged plants and the average was worked out.

3.7.1.3 Stem girth (cm) per plant

The circumference measured at the ground level of stem using vernier calipers and was taken as the stem girth and expressed in centimeter (cm).

3.7.1.4 Leaf area per plant (cm^{-2})

Leaf area was measured by used the following formula

Leaf Area = Leaf length (cm) x leaf width (cm) x 0.75

LA=L x W x 0.75 (cm^2)

The length of the fully opened leaf lamina was measured from the base of leaf to the tip of leaf. The leaf breath was taken at the midest point of the leaf lamina. The product of the leaf length and breadth was multiplied by the factor 0.75 (Singh and Saxena, 1965) and the sum of all leaves expressed as leaf area in cm^{-2} per plant.

3.7.1.5 Leaf area index per plant (LAI)

The leaf area index is defined as leaf area per unit land area (assimilatory source). It was calculated by dividing the leaf area per plant by the land area occupied by single plant (Sestak *et al.*, 1971).

$$LAI = \frac{A}{P}$$

Where,

LAI = Leaf area index

A = Leaf area (cm^2)

P = Unit land area (cm^2)

3.7.1.6 Days to Silking stage

No of days of silking stage in maize crop was taken number of days taken when 50% of the total plants bloom in each treatment. take reading treatment wise and show reading in days.

3.7.1.7 Absolute Growth Rate (AGR) (g/plant/day)

This was worked out by using formula given by Redford (1967), as indicated below.

$$AGR = \frac{(W2 - W1)}{(t2 - t1)}$$

Where,

AGR = Absolute growth rate (g/plant/day)

W1 and W2 = Dry weight of whole plant (g) at time 't1' and 't2' respectively

't1' and 't2' = Time interval (days)

3.7.1.8 Crop Growth Rate (CGR) (g/cm2/day)

It is defined as the rate of dry matter production per unit land area per unit time. It was worked out by using the following formula proposed by Watson (1952) and is expressed as 'g' per cm^{-2} per day.

$$CGR = \frac{W2 - W1)}{(t2 - t1)} \times \frac{1}{P}$$

Where,

W1 and W2= Dry matter production per plant (g) at time 't1' and 't2 respectively

P = Ground area covered by plant (cm^{-2})

3.7.1.9 Net Assimilation Rate (NAR) (g/cm2/day)

The net assimilation (NAR) is the rate of increase in dry weight per unit leaf area per unit time (Watson, 1952) and is expressed as grams per (cm^{-2}) day^{-1}. It was calculated by using following formula suggested by Redford (1967).

$$NAR = \frac{(W2 - W1)(\log_e L2 - \log_e L1)}{(t2 - t1)(L2 - L1)}$$

Where,

NAR = Net assimilation rate

L1 and L2, and W1 and W2 = Leaf area in cm^{-2} and dry weight of the plant in g at time'$t1$' and '$t2$' respectively.

$t2 - t1$ = Time interval (days)

Loge = Logarithm to the base "e" (Neperian constant)

3.7.1.10 Dry matter production and accumulation in different plant parts

The five plants each net plot were used to record the dry matter production at different day's intervals and different stages of growth. The sampled plants were separated into leaves, stem, roots and tassel cob with husk. These samples were dried at 65°C to 70°C to constant dry weight. Dry weight was recorded separately at each stage to assess dry matter accumulation in different parts of plant and total dry matter production was expressed in (g plant-^{1}).

3.8.2 Yield and yield parameters (At harvest)

The five randomly selected and tagged plants from each net plots are work out as in different yield parameter purpose yield parameters are given below:

3.8.2.1 Number of cobs per plant

From five randomly selected tagged plants from each net plot the total number of cobs were counted and recorded per plant. Their average was taken as the number of cobs per plant.

3.8.2.2 Weight of individual cob with husk (g)

The cobs from five randomly selected plants from each net plot were removed cob and was taken fresh weight per cob it was expressed in (g cob^{-1})

3.8.2.3 Weight of Individual cob without husk (g)

The cobs from five randomly selected plants from each net plot were removed cob and were taken without husk individual cob weight and it expressed in (g cob^{-1}).

3.8.2.4 Number of grains per cob

The number of grains per cob was calculated as follows Number of grains per cob = Number of grain rows per cob x Number of grains per row.

3.8.2.5 Cob length (cm)

The length of the cob was measured from five randomly selected plants each net plot from base to the tip of the cob with husk and expressed in centimeter (cm).

3.8.2.6 Grain weight per plant (g)

The grains from five randomly selected plants were separated and dried in room the weight of the grains was recorded. The average grain weight per plant was expressed as g plant^{-1}.

3.8.2.7 Test Weight (g)

The weight of 100 dried grains was recorded from the grain samples drawn from the produce obtained from five randomly selected plants from each of the net plot and it expressed as (g)

3.8.2.8 Grain yield (q ha^{-1})

At physiological maturity cobs from each net plot were harvested. Cobs were separated and air dried, shelled, cleaned and weighed. Grain yield ha^{-1} was worked out and expressed in (q ha^{-1})

3.8.2.9 Harvest index (%)

Harvest index is defined as the ratio of economic yield to total biological yield (Donald 1962) and expressed in percentage. The harvest index for maize was worked out as indicated below:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (q ha}^{-1}\text{)}}{\text{Total biological yield (q ha}^{-1}\text{)}} \times 100$$

3.9 Chemical analysis plant and soil

Nitrogen, phosphorus and potassium content of stem leaves and cob at harvest was estimated by micro-kjeldahl assembly (Jackson, 1973), vandomlybdate phosphoric acid yellow colour method (Jackson, 1973) and flame photometer method (Jackson,1973) the plant samples collected for dry matter production were utilized for chemical analysis plant parts were separated into leaves, stem and cob. The dried samples of leaves stem and cob were crush powered (100 mesh) together and used for analysis. for 0.5 g final ground sample used.

3.9.1 N content of plant sample

Nitrogen content of stem leaves and cob at harvest was estimated by add 20 ml conc. H_2SO_4 2.5 g digestion mixture and keep it overnight. distillation assembly, digestion flask and burette Next day digest the material first on heat gently with the help of hot plate till the material become colorless, add 10 ml distil water shake, and make volume 100 by mixing after cooling.

Start distillation take 5 ml of aliquot in micro-kjeldahl apparatus and add 10 ml of 40% NaOH slowly. Distil it till 100 ml of distillate is collected in 10 ml of 4% working boric acid(with mixed indicator) in conical flask and titrate content against 0.02 H_2SO_4 till colour change from blue to red wine again note reading and run blank sample without adding aliquot note that reading too.

3.9.2 P content of plant sample

Phosphorus content of stem leaves and cob at harvest was estimated by add in di-acid mixture make volume 100 ml take 5 ml aliquot in 25 ml flask, add 10 ml distilled water and 5 ml vando–molybdate solution, make volume to 25 ml with distilled by mixing thoroughly after 20 minute the yellow colour develops note the readings either in transmission optical density at 470 nm. Wavelength warm up the instrument for half an hour before taking readings. From standard curve, determine p concentration.

3.9.3 K content of plant sample

Potassium content of stem leaves and cob at harvest was estimated by digest plant sample in Di acid method and make volume 100 ml , and setting the instrument with standard solution of K take a small quantity of aliquot and feed it flame photometer , note reading unknown sample and compare it with the standard curve and calculate K concentration.

3.10. Uptake of N, P and K

Total N, P and K uptake was calculated for each treatment separately using the

Following formula:

$$\text{Nutrient uptake} = \frac{\text{Percent of nutrient concentration}}{100} \times \text{Biomass} \quad (\text{kg ha}^{-1})$$

Uptake of N, P and K were expressed in kg per hectare.

3.10.1. Nitrogen uptake by maize (kg ha-^{1})

It was calculated by estimating the nitrogen concentration in stem, leaves, cob and Multiplied by total biomass (kg ha-1) of shoot and divided by 100. It was expressed in kg ha-^{1}.

The total nitrogen content in the plant samples of stem, leaves, and cob at harvest was estimated by following modified microjeldal method (Jackson, 1973).

3.10.2. Phosphorus uptake by maize (kg ha-^{1})

It was calculated by estimating the phosphorus concentration in stem, leaves, cob and multiplied by total biomass (kg ha-^{1}) of shoot and divided by 100. It was expressed in kg ha-^{1}.

Total phosphorus and potassium of plant samples at harvest were extracted by wet oxidation method using triacid mixture (conc. HNO_3:H_2SO_4:$HClO_4$ in 10:1:4 ratio). Phosphorus content was estimated by vanadomolybdate yellow colour method (Jackson, 1973).

3.10.3. Potassium uptake by maize (kg ha-^{1}).

It was calculated by estimating the potassium concentration in stem, leaves, cob and multiplied by total biomass (kg ha-^{1}) of shoot and divided by 100. It was expressed in kg ha-^{1}.

Potassium content was determined by flame photometer method (Jackson, 1973) and expressed in percentage.

3.11 Chemical properties of soil

3.11.1 Soil sampling and Analysis

Before sowing of crop in experimental site, composite soil samples from depth 0-30 cm were collected and processed to pass through 2 mm sieve and preserved for further analysis. Similarly the representative soil samples from each plot according to treatment were collected after harvest of maize crop. The soil samples were dried in room temperature, processed to pass through 2 mm sieve and used for further analysis. The soil samples were analyzed for organic carbon, available nitrogen, phosphorus and potassium content of the soil.

3.11.2. pH and Electrical conductivity

The soil pH was measured in 1: 2.5 soil water suspensions by Potentiometer (Piper, 1966). The clear supernatant solution of above soil water suspension was taken and electrical conductivity was measured using Conductivity Bridge (Jackson, 1967).

3.11.3. Organic carbon

The organic carbon was determined by Walkley and Black’s wet oxidation method by oxidizing organic matter as described by (Jackson, 1973). It was expressed in percent.

3.11.4. Available nitrogen

The available nitrogen was estimated by micro kjeldahl method as outlined by (Jackson, 1973). It was expressed in kg ha^{-1}.

3.11.5. Available phosphorus

The available phosphorus was determined by Olsen’s method using spectrophotometer (660 nm wave length) as outlined by (Jackson, 1973). It was expressed in kg ha^{-1}.

3.11.6. Available potassium

The available potassium was extracted with neutral normal ammonium acetate (1 N NH4 OAC) and the content of K in the solution was estimated by Flame photometers (Jackson, 1973). It was expressed in kg ha^{-1}.

3.12 Statistical analysis and interpretation of data

The data collected from the experiment at different growth yield and nutrient uptake were subjected to statistical analysis as described by Gomez and Gomez (1984). Statistical analysis was carried out by taking the averages of the five plants from each net plot. The level of significance used in ‘F’ and‘t’ test was P=0.05. Critical difference valves were calculated wherever, the‘F” test was significant.

4. RESULTS AND DISCUSSION

The results of the investigations on “Impact of crop geometry on growth and yield of maize (*Zea mays*) in Punjab alluvial soils. This research conducted at Main Agricultural field of Lovely Professional University during *rabi* Season 2013-2014 which presented in this chapter.

The different crop geometry and plant population are T_1: recommended spacing (60cm x 20cm, 83,333 plant ha^{-1}). T_2: square planting (30cm x 30cm, 1,11,111 plant ha^{-1}), T_3: Skip row planting (planting 2 row followed by1 row skipping model, 77,777 plant ha^{-1}), T_4: low plant population (60cm x 30cm 55,555 plant ha^{-1}) , T_5: high plant density (30cm x 15cm plant 2,22,222 ha-^{1}) and T_6: medium high plant density (60cm x 10cm plant, 1,66,666 ha^{-1}).

4.1 Growth parameters

4.1.1 Plant height (cm)

Variations in plant height due to different crop geometry and planting population density ha^{-1} were found to be significant at all stages of growth. Plant height of maize crop increased with an advancement of crop growth and the higher magnitude of increase was observed between 75 and 150 days after sowing (DAS) and data was presented in Table 4.1. At all growth stages (30, 45, 60, and 75,150 DAS and at harvest) result shown higher plant population density ha^{-1} (30cm x 15cm) having significantly taller plant (table 4.1.), at harvest (160.30cm) followed by medium high plant density ha^{-1} (60cm x 10cm) (158.73 cm) as compared to recommended spacing (60cm x 20cm) (146.87 cm).

At all this interval recorded high plant height in (30cm x 15 cm) increased plant population density ha^{-1} and narrow row spacing it increased plant height because maize considered as photoperiod loving crop and also in high population density, the competition was intense (within the species) to compete dense populated treatment promoting taller growth with angular leaves for higher absorption of sunlight and photosynthesis. Similar work found by Agasibagil (2006) who reported, at spacing of 45cm x 20cm, obtained more height and concluded increased plant population ha^{-1} increases plant height, Hussein F and Abouzien (2008) fount contrary reports saying wider row spacing recorded lower plant height as compared to narrow row spacing.

Table 4.1: Plant height (cm) of maize as influenced by crop geometry.

Treatment	Plant height (cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At Harvest
T_1 recommended spacing	27.63a	42.93a	53.17a	68.67a	139.67a	146.87a
T_2 Square planting	28.17ab	44.37ab	55.27b	70.73b	140.40ab	148.80b
T_3 Skip row	28.18ab	43.27ab	54.47ab	69.90ab	142.40b	151.17c
T_4 Low plant density	27.99a	44.87b	54.93b	71.20b	141.87b	152.27c
T_5 High plant density	29.19b	48.80c	56.83c	75.13c	146.87c	160.30d
T_6 Medium high plant density	28.23ab	47.87b	55.57b	72.93c	144.41c	158.73d
S.E.+	0.53	0.88	0.75	0.73	0.71	0.88
C.D @ 5%	1.09	1.81	1.68	1.52	1.47	1.82

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.2 Number of green leaves per plant

Number of green leaves plant^{-1} increased up to 75 DAS, while it declined marginally at 150 DAS and also at harvest. Crop geometry differs significantly in respect to number of green leaves plant^{-1} at all stage of growth and data was represented in Table 4.2.

Result shown in table 4.2 that at all crop growth stages (30, 45, 60, 75,150 at harvest) found more number of green leaves plant^{-1} at medium high plant population density ha^{-1} (60cm x 10cm) at harvest (9.7) followed by high population density ha^{-1} (30cm x 15cm) (9.3) as compared to recommended spacing (60cm x 20cm) found lower number of green leaves (8.5 plant$^{-1)}$.

Increase in plant population density ha^{-1} and narrow spacing between plant to plant resulted an influence plant height at all growth stages. If plant height was taller than the number of green leaves plant^{-1} also increases as compared to low plant population density ha^{-1}.

Increased plant population m-^{2} also cause higher number of leaves plant^{-1} Emam *et al*.,

(1999) Similar result was also expressed by Kole (2010) who reported if plant to plant distance decreased 20 cm to 10 cm it increased number of green leaves plant^{-1}.

Table 4.2: Number of green leaves per plant of maize as influenced by crop geometry.

Treatment	Number of Green leaves per plant					
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**150 DAS**	**At harvest**
T_1 recommended spacing	5.1a	9.4a	11.7a	13.4a	11.4a	8.5a
T_2 Square planting	5.3ab	9.6ab	12.5b	13.6ab	12.0ab	8.7a
T_3 Skip row	5.4ab	9.7ab	12.4b	13.9ab	12.5b	9.2ab
T_4 Low plant density	5.5b	9.6ab	12.3ab	13.8ab	11.9ab	8.8a
T_5 High plant density	5.4ab	9.5ab	12.6b	13.6ab	12.0ab	9.3ab
T_6 Medium high plant density	5.6b	9.8b	12.7b	14.1b	12.3b	9.7b
S.E.+	0.14	0.11	0.27	0.20	0.35	0.41
C.D @ 5%	0.30	0.23	0.57	0.42	0.72	0.84

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.3 Stem girth (cm) per plant

Crop geometry differs significantly in respect of stem girth plant^{-1} (cm) at all growth stages and data was presented in Table 4.3.

Results shown in table 4.3 that At all crop growth stages (30, 45, 60, 75, 150 and at harvest) the stem girth plant^{-1} (cm) were significantly higher at low plant population density ha^{-1} (60cm x 30cm) followed by (skip row planting) as compare to medium high plant population density ha^{-1} (60cm x 10cm).

Decreased plant population density ha^{-1} and wider plant to plant and row to row spacing recorded significantly more stem girth at all growth stages, Low plant population density ha^{-1} and wider spacing decreases the intra specific competition between plant to plant, increasing photosynthetic activity resulting in more vegetative growth and causes higher stem girth plant^{-1}.Same result was obtained in two different experiment conducted by Toaima *et al*., (2001) and Crowaer *et al*., (1967)

Table 4.3: Stem girth per plant of maize (cm) as influenced by crop geometry.

Treatment	Stem girth (cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At harvest
T_1 recommended spacing	4.33a	7.10ab	8.40a	9.40a	9.67a	10.11ab
T_2 Square planting	4.43ab	7.17ab	8.47a	9.47a	9.57a	10.29b
T_3 Skip row	4.37a	7.13ab	8.53ab	9.50a	9.70ab	10.18ab
T_4 Low plant density	4.80b	7.40b	8.80b	9.87b	10.07b	10.35b
T_5 High plant density	4.53ab	7.30b	8.57ab	9.53ab	9.80ab	10.14ab
T_6 Medium high plant density	4.23a	6.97a	8.37a	9.20a	9.57a	10.07a
S.E.+	0.18	0.14	0.14	0.17	0.15	0.10
C.D @ 5%	0.38	0.29	0.28	0.36	0.35	0.21

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.4 Leaf area per plant (cm^2)

Crop geometry differed significantly with respect of leaf area per plant (cm^2 plant-^{1}) at all growth stages data represented in Table 4.4.

At all growth stages (30,45,60,75,150 and at harvest), high plant population density ha^{-1} (30cm x 15cm) recorded significantly higher leaf area $plant^{-1}$ followed by low plant population density ha^{-1} as compared to recommended spacing (60cm x 20cm).

Increased plant population density ha^{-1} influenced leaf area $plant^{-1}$ cm^2, high plant population density ha^{-1} recorded more leaf area $plant^{-1}$ cm^2 because of structural compartment of the plant leaves increases more rapidly and the size of leaf become larger, making narrow leaf angle and results in higher leaf area found in high plant population density ha^{-1}.

Similar work was done before by Kole (2010) showing increased plant population ha^{-1} increases leaf area cm^2 $plant^{-1}$ Maddonni (2001) reported if plant density decreased ha^{-1} lesser leaf area $plant^{-1}$ maize.

Table 4.4: Leaf area per plant (cm^2) Maize as influenced by crop geometry.

Treatment	Leaf area per plant (cm^{-2})					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At harvest
T_1 recommended spacing	91.1a	221.3a	265.9a	336.2a	360.3b	400.9a
T_2 Square planting	92.1a	222.0a	268.8b	339.7b	361.2b	413.7c
T_3 Skip row	92.6a	227.1b	275.1c	342.4c	361.4b	408.5b
T_4 Low plant density	91.4a	235.7c	277.2c	343.3c	357.8a	416.6d
T_5 High plant density	101.0b	246.9d	287.4d	351.7e	363.8c	419.5e
T_6 Medium high plant density	98.2b	226.4b	274.5c	345.5d	365.7c	415.8c
S.E.+	1.24	1.08	1.25	1.64	1.14	1.13
C.D @ 5%	2.56	2.08	2.57	2.47	2.35	2.33

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.5 Leaf area index per plant (LAI)

Crop geometry differed significantly with respect of leaf area index (LAI) at all stages of crop growth data presented in Table 4.5.

At (30,45,60,75 and 150 DAS), high plant population density ha^{-1}(30cm x 15cm) recorded significantly high leaf area index cm^{-2} followed by low plant population density ha^{-1} as compared to medium high plant population density ha^{-1} (60cm x 10cm).

At harvest low plant density ha^{-1} recorded significantly higher leaf area index (1.93 cm^{-2}) followed by square planting (30cm x 30cm), (1.81 cm^{-2}) as compared to high plant population density ha^{-1} (30cm x 15cm), (1.68 cm^{-2}).

During all the crop growth stages, increased plant population density ha^{-1} resulted in more leaf area index except at harvesting stage. As plant population density/ha increases, the plant height was much taller, leaf becomes narrow and elongated and there is more competition for sunlight between leaf surface, resulting in higher LAI as compared to low plant population density ha^{-1} Similar work was done by Kole (2010) sharing similar findings. Also similar data inline by Maddonni (2001) and Eman *et al*., (1999)

At harvest spacing (60cm x 30) cm obtained high leaf area because of low plant population density ha^{-1} and wider plant spacing providing less plant competition than high plant population density ha^{-1} at harvest by Agasibagil (2006)

Table 4.5: Leaf area index per plant of maize as influenced by crop geometry.

Treatment	Leaf area Index (LAI)					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At harvest
T_1 recommended spacing	0.62ab	0.69a	0.77a	1.08ab	1.62ab	1.77ab
T_2 Square planting	0.65b	0.71a	0.79ab	1.02a	1.63ab	1.81ab
T_3 Skip row	0.65b	0.72ab	0.79ab	1.00a	1.66b	1.76ab
T_4 Low plant density	0.71c	0.75b	0.83b	1.08ab	1.56a	1.93b
T_5 High plant density	0.73c	0.76b	0.85b	1.17b	1.77c	1.68a
T_6 Medium high plant density	0.60a	0.70a	0.78ab	0.96a	1.59ab	1.71a
S.E.+	0.01	0.01	0.02	0.07	0.04	0.08
C.D @ 5%	0.030	0.031	0.043	0.14	0.09	0.17

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.6 Days to Silking stage.

Crop geometry and different plant population density ha^{-1} had significantly influence on the days taken for 50 % silking stage and data presented in Table 4.6.

Skip row planting (planting 2 row followed by skip 1 row model) took significantly less days to 50% silking (106.3 days) followed by square planting (30cm x 30cm) (107.7 days) as compared medium high plant population density ha^{-1} took more days of 50% silking(116.3 days).

Both the special arrangement in skip row planting and square planting minimized the nutrient competition providing more space for plant growth and development thereby enhancing early silking stage. On other hand normal planting and higher plant population density ha^{-1} significantly increased days of 50% silking days it happened due to limited availability of natural resources (nutrients, moisture) and narrow space between the plants. The maturity period got delay due to higher competition of nutrients and cob formation starts late similar sharing by Abraha Lemlem (2013)

Skip row planting plant mature earlier because of wider plant space and low plant population density ha^{-1} showing less competition and availability of nutrients sharing similar result by Jithendra *et al.*, (2013) with their germplasm under their conditions.

4.1.7 Absolute Growth Rate (AGR) (g/plant/day)

Crop geometry differs significantly with respect of absolute growth rate at all crop growth stages data was represented Table 4.6.

At 30,DAS, skip row planting, (planting 2 row followed by skip 1 row model) recorded higher absolute growth rate (0.18 g/plant/day) followed by low plant population density ha^{-1} (60cm x 30cm) (0.179 g/plant/day) as compared to recommended spacing (60cm x 20cm) (0.171 g/plant/day).

At 45 and 60 DAS, (30cm x 30cm) square planting recorded significantly higher absolute growth rate (1.1 and 1.4 g/plant/day 45 and 60 DAS respectively) followed by (30cm x 15cm) high density planting (1.067 and 1.307 g/plant/day 45 and 60 DAS respectively) as compared to (60cm x 10cm) medium high plant population density ha^{-1} (0.950 and 1.323 g/plant/day 45 and 60 DAS respectively.

At 75 DAS,(60cm x 30cm) low plant density recorded high AGR (0.73 g/plant/day) as compared to (30cm x 30cm) square planting (0.40 g/plant/day).at 150 DAS skip row planting recorded high AGR (1.61 g/plant/day) as compared to (30cm x 15cm) (1.48g/plant/day) high plant population density ha^{-1}.

Since maize crop are highly sensitive to lower temperature during the crop growth stage. Similar after 65 DAS due to low temperature, chilling injury occurs in the field, resulting in lower metabolic processes of plant and reducing the dry matter production causing less vegetative growth.

During different crop growth stages variation in absolute growth rate were observed because of plant population density, variation in dry matter production $plant^{-1}$. If dry matter production was increased $plant^{-1}$ than it increased the AGR also. As a result in low density planting, skip row planting show higher AGR as compared to high density planting and medium high density planting.

Plant population increased ha^{-1} resulted to lower light interception, produce less dry matter production $plant^{-1}$ which was correlated with low absolute growth rate (g/plant/day) and similar views were also expressed by Amanullah *et al*., (2010)

Table 4.6: Absolute growth rate (AGR) (g /plant /day), Days of silking stage maize as influenced by crop geometry.

Treatment	Absolute growth rate(AGR) g/per/day)						
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**	**150 DAS**	**At Harvest**	**Days of Silking**
T_1 recommended spacing	0.168a	1.057c	1.380b	0.580b	1.580b	1.167a	112.3b
T_2 Square planting	0.176ab	1.080c	1.400b	0.400a	1.543a	1.410b	107.7a
T_3 Skip row	0.182b	1.033bc	1.398b	0.593b	1.607b	1.260ab	106.3a
T_4 Low plant density	0.179b	1.033bc	1.297a	0.730c	1.560ab	1.287ab	108a
T_5 High plant density	0.174ab	1.067c	1.307a	0.600b	1.483a	1.243a	113.7b
T_6 Medium high plant density	0.176ab	0.950a	1.323ab	0.607b	1.543a	1.213a	116.3c
S.E.+	0.004	0.03	0.02	0.02	0.06	0.07	1.02
C.D @ 5%	0.0093	0.07	0.05	0.05	0.13	0.15	2.11

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.8 Crop Growth Rate (CGR) (g/cm^2 /day)

Crop geometry significantly differs at all crop growth stages with respect of crop growth rate (CGR) while data were represented in Table 4.7.

At 30 DAS, low plant population density ha^{-1} (60cm x 30cm), were recorded significantly high crop growth rate (0.0013 g/cm^2/day) followed by skip row planting (0.0012 g/cm^2/day) as compared to medium high plant population density ha^{-1} (60cm x 10cm) (0.00104 g/cm^2/day). But at later stages (45 and 60 DAS), recommended spacing (60cm x 20cm) showed significantly high crop growth rate (0.0033, 0.004 g/cm^2/day at 45 and 60 DAS respectively) followed by square planting (30cm x 30cm), (0.0032, 0.003g/cm^2/day at 45 and 60 DAS respectively) as compared to medium high plant population density ha^{-1} (60cm x 10cm), (0.00104,0.00261 g/cm^2/day).

At 75, DAS, low plant population density ha^{-1} (60cm x 30cm), recorded significantly high crop growth rate (0.00221 $g/cm^2/day$) as compared to square planting, (30cm x 30cm), (0.00115 $g/cm^2/day$). At 150, DAS, skip row planting plant 2 row followed by skip 1 row model recorded significantly high CGR (0.00727 $g/cm^2/day$) as compared to low plant population density ha^{-1} (60cm x 30cm), (0.00666 $g/cm^{-2}/day$, respectively).

At harvest, square planting (30cm x 30cm), recorded significantly high crop growth rate (0.00588 $g/cm^2/day$) as compared to medium high plant population density ha^{-1} (60cm x 10cm), (0.00485 $g/cm^2/day$).

Increased plant population density ha^{-1} it significantly decreased crop growth rate at all crop growth stages. Low plant density, skip row planting, and recommended spacing recorded higher crop growth rate as compared to high plant population density ha^{-1} and medium high plant population density ha^{-1}.

After 60 DAS there was decline in min temperature that resulted in low metabolic process which influences the CGR in negative manner.

Difference in CGR at all crop growth stages was observed because of difference in dry matter production $plant^{-1}$, if dry matter $plant^{-1}$ were high respectively higher will be crop growth rate. At low plant density ha^{-1} resulted in higher dry matter production $plant^{-1}$ that directly leads to higher CGR as compared to high plant population density ha^{-1} similar result obtained by Ocloo *et al*., (2011)

Abeleke *et al.*, (2013) reported if plant population low ha^{-1} and wider row spacing was used, it influenced crop growth rate of maize because of low plant competition for survival and plant are healthy, vigorous also absorb more light nutrient result to high dry matter production $plant^{-1}$ and increased crop growth rate (CGR).

Table 4.7: Crop growth rate (CGR)(g/cm^2 /days) influenced by crop geometry.

Treatment	Crop growth rate (CGR)(g/cm^2/days)					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At harvest
T_1recommended spacing	0.00111a	0.00334b	0.00419b	0.00175bc	0.00703ab	0.00516ab
T_2 Square planting	0.00122ab	0.00325b	0.00399b	0.00115a	0.00697ab	0.00588b
T_3 Skip row	0.00122ab	0.00314ab	0.00382ab	0.00168b	0.00727b	0.00525ab
T_4 Low plant density	0.00136b	0.00325b	0.00382ab	0.00221c	0.00666a	0.00554ab
T_5 High plant density	0.00118ab	0.00325b	0.00382ab	0.00188bc	0.00722b	0.00492a
T_6 Medium high plant density	0.00104a	0.00261a	0.00349a	0.00166b	0.00667a	0.00485a
S.E.+	0.00010	0.00019	0.00017	0.00023	0.00021	0.00035
C.D @ 5%	0.00020	0.00040	0.00035	0.00048	0.00044	0.00072

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.9 Net Assimilation Rate (NAR) (g/cm^2/day)

Crop geometry differs significantly with respect of net assimilation rate at all crop growth stages except at harvest data represented in Table 4.8.

At 30, 45, DAS, square planting (30cm x 30cm), recorded significantly higher net assimilation rate (0.0020,0.0048, g/cm^2/day at 30,45, DAS respectively) followed by recommended spacing (60cm x 20cm), (0.0017,0.0047 g/cm^2/day at 30,45, DAS respectively) as compared to medium high plant population density ha^{-1} (60cm x 10cm), (0.0017,0.0042 g/cm^2 /day at 30,45, DAS respectively).

At 60, DAS, recommended spacing of maize (60cm x 20cm), recorded significantly high Net Assimilation Rate (0.0052 g/cm^2 /day) followed by square planting (30cm x 30cm), (0.0051 g/cm^2 /day) as compared to low plant population density ha^{-1} (60cm x 30cm), (0.0046 g/cm^2 /day).

At 75, DAS, (60cm x 30cm) low density planting recorded significantly high net assimilation rate (0.0021 g/cm^2 /day) as compared to (30cm x 30cm) square planting (0.0011 g/cm^2 /day). At 150, DAS, (skip row planting) plant 2 row followed, by skip 1 row model recorded higher net assimilation rate (0.0044 g/cm^2 /day) as compared to (30cm x 15cm) (0.0040 g/cm^2 /day).

At harvest crop geometry not shown significantly affect in term of NAR. At all crop growth stages square planting, skip row planting, recommended spacing and low plant population density planting recorded highest net assimilation rate as compared to high plant population density ha^{-1} and medium high plant population density ha^{-1}

Increased plant density ha^{-1} resulted in decrease NAR due to low photosynthetic rate which directly affect the dry matter production among the plants for as per the findings of Ishaque *et al.,* (2010) With the increase in plant population there was decrease in NAR revealed by Amanullah *et al.,* (2010) with their crop under their conditions.

4.1.10 Dry matter production and its distribution (g) plant

4.1.10.1 Dry matter accumulation in leaves (g)

Crop geometry had significant influence on leaf dry weight with all crop growth stages and data represented in Table 4.9.

At 30, DAS, medium high plant density ha^{-1} (60cm x 10cm), recorded significantly higher leaf dry weight (2.88 g $plant^{-1}$) followed by square planting (30cm x 30cm), (2.77 g $plant^{-1}$ as compared to high plant population density ha^{-1} (30cm x 15cm), (2.63 g $plant^{-1}$).

At 45, DAS, (30cm x 15cm) high plant population density ha^{-1} recorded significantly high leaf dry weight (12.73 g $plant^{-1}$) followed by (30cm x 30cm) square planting (12.60 g $plant^{-1}$) compared to (60cm x 10cm) (12.04 g $plant^{-1}$).

At 60, DAS, (30cm x 30cm) square planting recorded significantly high leaf dry weight (22.66 g $plant^{-1}$) followed by (60cm x 20cm) recommended spacing (22.43 g $plant^{-1}$) as compared to (60cm x 30cm) (21.82 g $plant^{-1}$)

At,75 DAS,(60cm x 30cm) low plant density planting recorded significantly high leaf dry weight (28.90 g $plant^{-1}$ as compared to (30cm x 30cm) square planting (27.45 g $plant^{-1}$) At 150 DAS and at harvest (30cm x 30cm square planting) recorded significantly high dry weight (22.69,17.90 g $plant^{-1}$ 150 DAS, at harvest respectively) as compared to (60cm x 10cm) (21.59,16.31 g $plant^{-1}$ 150 DAS, at harvest respectively).

Increased plant population ha^{-1} at 30 DAS increased leaf dry weight but from 45 DAS to harvest decreased leaf dry weight was reported due to narrow leaves in higher plant density ha^{-1}, these results are in agreement with Kole (2010). Agasibagil (2006) expressed dense planting resulted in lesser leaf dry matter.

Table 4.8: Net assimilation rate (NAR) (g/cm^2 /day) influenced by crop geometry.

Treatment	Net assimilation rate (NAR) (g/cm2/day)					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At harvest
T_1 recommended spacing	0.0017ab	0.0047b	0.0052c	0.0016b	0.0043bc	0.0028a
T_2 Square planting	0.0020b	0.0048b	0.0051b	0.0011a	0.0042b	0.0034c
T_3 Skip row	0.0019b	0.0045ab	0.0049b	0.0017b	0.0044c	0.003b
T_4 Low plant density	0.0018b	0.0044a	0.0046ab	0.0021c	0.0042b	0.0028ab
T_5 High plant density	0.0016a	0.0043a	0.0045a	0.0016b	0.004a	0.0029ab
T_6 Medium high plant density	0.0017	0.0042a	0.0048ab	0.0017b	0.0042b	0.0029ab
S.E.+	0.00005	0.00015	0.00011	0.00006	0.00006	0.00011
C.D @ 5%	0.00012	0.00031	0.00023	0.00015	0.00014	0.00024

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference P$\leq$ 0.05 % (Duncan's multiple range test).

4.1.10.2 Dry matter accumulation in stem (g)

Crop geometry differs significantly with respect of stem dry matter at all stages of crop growth data represented in Table 4.10.

At 30 and 60 DAS, dry matter accumulation in stem is differs significantly, lower plant population density ha^{-1} (60cm x 30cm) recorded higher stem dry weight (2.61 g plant^{-1}) compared with medium high plant population ha^{-1} (60cm x 10cm), (2.41g plant^{-1}) and recommended spacing (60cm x 20cm), (2.55 g plant^{-1}) .

At 45 and 60 DAS, square planting (30cm x 30cm) recorded significantly high dry matter accumulation in stem (9.06, 20.09 g plant^{-1}45,60 DAS respectively) as compared to (60cm x 10cm) (7.58 ,17.56 g plant^{-1} 45,60 DAS respectively) low stem dry matter accumulation.

At 150 DAS, and harvest (Skip row planting) recorded significantly higher stem dry matter accumulation (34.47 and 39.46 g plant^{-1}) respectively as compared to (30cm x 15cm) (33.32 and 37.39 g plant^{-1}) respectively.

Increased plant population density ha^{-1} results negative effect on stem dry matter production plant^{-1} due to not linking association with the roots as per findings of Kole (2010).

During all crop growth stages dense planting significantly decreased dry matter accumulation in stem and similar results obtained by Ahmad *et al.*, (2010) and Agasibagil (2006).

4.1.10.3 Dry matter accumulation in tassel (g)

Crop geometry differed significantly for dry matter accumulation in tassel At 150 DAS, and at harvest data was presented in Table 4.11.

At 150 DAS, (60cm x 30cm) low plant population density ha^{-1} recorded significantly higher dry matter accumulation in tassel (2.60 g $plant^{-1}$) followed by high population density (30cm x 15cm), (2.46 g $plant^{-1}$) as compared to medium high plant population density (60cm x 10cm), (1.98,g $plant^{-1}$) . At harvest (60cm x 30cm) low plant population density ha^{-1} recorded significantly high tassel dry weight (2.81 g $plant^{-1}$) followed by (30cm x 15cm) high plant population density ha^{-1} (2.50 g $plant^{-1}$).

In low plant population density ha^{-1} was recorded the highest tassel dry matter because of in low plant density plant growth and tassel was come early as compared to high plant population density $ha^{-1}$and stay vigorous for more time span. Crop geometry significantly influence tassel dry matter if plant to plant spacing wider result in increased tassel dry matter as per data inline by Ibeawuchi *et al*., (2008).

Table 4.9 Dry matter accumulation in leaves (g) influenced by crop geometry.

Treatment	Leaves dry matter accumulation (g) $plant^{-1}$					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At Harvest
T_1 recommended spacing	2.66a	12.53b	22.43b	28.44bc	22.63b	17.80b
T_2 Square planting	2.77ab	12.60b	22.66b	27.45a	22.92c	17.90b
T_3 Skip row	2.68a	12.38ab	22.00ab	28.21bc	22.69b	17.62b
T_4 Low plant density	2.68a	12.20ab	21.82a	28.90c	22.66b	16.87ab
T_5 High plant density	2.63a	12.73b	22.29ab	28.14b	22.61b	17.40b
T_6 Medium high plant density	2.88b	12.04a	21.99ab	28.68c	21.59a	16.31a
S.E.+	0.06	0.20	0.24	0.24	0.27	0.34
C.D @ 5%	0.15	0.42	0.50	0.49	0.55	0.70

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

Table 4.10: Dry matter accumulation in stem (g) influenced by crop geometry.

Treatment	Stem dry matter accumulation (g) plant^{-1}					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At Harvest
T_1 recommended	2.55b	8.56b	19.43c	22.21b	33.91b	38.29b
T_2 square planting	2.59b	9.06c	20.09d	22.04b	32.92a	38.23b
T_3 Skip row	2.61b	8.44b	19.42c	22.24b	34.47b	39.46c
T_4 60 x 30 cm	2.61b	8.62b	18.48b	22.22b	33.53ab	38.28b
T_5 30 x 15 cm	2.54b	8.53b	18.63b	22.38b	33.32a	37.39a
T_6 60 x 10 cm	2.41a	7.58a	17.56a	20.87a	33.96b	38.35b
S.E.+	0.05	0.20	0.30	0.40	0.42	0.23
C.D @ 5%	0.11	0.43	0.63	0.83	0.88	0.48

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.1.10.4 Dry matter accumulation in cob (g)

Crop geometry differed significantly in cob dry weight accumulation at all the crop growth stages data presented in Table 4.11.

At 150 DAS, and at harvest (skip row planting) recorded significantly higher cob weight (112.0, 130.7 g plant^{-1} at 150 DAS and at harvest respectively) followed by (60cm x 20cm) recommended spacing (110.9, 129.0 g plant^{-1} at 150 DAS and at harvest respectively) as compared to (30cm x 15cm) high plant population density ha^{-1} (107.2, 126.9 g plant^{-1} at 150 DAS and at harvest respectively).

In present study plant was affected by chilling injury at 60 DAS and it cause on the slow metabolic process in maize plant and decrease photosynthesis performance which resulted lesser plant growth as well as lower dry matter of cob.

With plant to plant spacing narrow and dense plant population ha^{-1} significantly decreased cob dry matter accumulation plant^{-1} similar views were also expressed by Kole (2010)

4.1.10.5 Total dry matter production (TDMP) (g/plant)

Crop geometry differed significantly for total dry matter (g plant^{-1}) at 30, 45, 60, DAS and at harvest data represented in Table 4.12.

At 30 DAS,(30cm x 30cm) square planting recorded significantly high dry matter production(5.5 g plant^{-1}) followed by (skip row planting) plant 2 row, followed by skip 1 row model (5.3 g plant^{-1}) as compared to (30cm x 15cm) (5.2 g plant^{-1}).

At 45, DAS, (60cm x 30cm) obtained significantly high total dry matter (22.2 g plant^{-1}) followed by (30cm x 30cm) skip row planting(22.0 g plant^{-1}) as compared to (60cm x 10cm) medium high plant population density ha^{-1} (19.6 g plant^{-1}).

At 60, DAS, (30cm x 30cm) square planting recorded significantly high total dry matter production (43.1 g plant^{-1}) followed by (60cm x 20cm) recorded spacing (41.9 g plant^{-1}) as compared to (60cm x 10cm) (39.5 g plant^{-1}).

At 75, DAS,(60cm x 30cm) recorded significantly high total dry matter (52.5 g plant^{-1}) followed by (60cm x 20cm) recommended spacing (50.0 g plant^{-1}) as compared to (30cm x 30cm) square planting(49.3 g plant^{-1}).

At harvest (skip row planting) recorded significantly high total dry matter production (190.2 g plant^{-1}) followed by (60cm x 30cm) low plant population density ha^{-1} (186.9 g plant^{-1}) as compared to (30cm x 15cm) (184.1 g plant^{-1}).

At all crop growth stages higher plant population density ha^{-1} and medium high plant population ha^{-1} recorded low dry matter production plant^{-1} as compared to low population density ha^{-1},square planting and skip row planting these result are conformity with Ahmad *et al*., (2010) and Ibeawuchi et *al.*, (2008).

Increased plant population ha^{-1} result to decreased total dry matter production (TDMP) plant^{-1} because of narrow space between plant to plant there will be less root penetration the plant growth was low as compared to low plant population density ha^{-1} similar findings was revealed by Dalvi (1984)

Table 4.11: Dry matter accumulation in tassel and cob (g plant^{-1}) influenced by crop geometry.

Treatment	DMA (g plant^{-1}) in tassel		DMA (g plant^{-1}) in cob	
	150 DAS	At harvest	150 DAS	At Harvest
T_1 recommended spacing	2.02a	2.33ab	110.9b	128.5b
T_2 square planting	2.15c	2.33ab	107.3a	127.9ab
T_3 Skip row	2.10b	2.40b	112.0b	130.7c
T_4 60 x 30 cm	2.60d	2.81c	110.3b	129.0b
T_5 30 x 15 cm	2.46d	2.50b	107.2a	126.9a
T_6 60 x 10 cm	1.98a	2.24a	108.4ab	127.2a
S.E.+	0.045	0.05	0.96	0.54
C.D @ 5%	0.092	0.11	1.97	1.11

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

Table 4.12: Total dry matter production (TDMP) (g/plant) at 30,45,60,150 and at harvest influenced by crop geometry.

Treatment	Total dry matter accumulation g plant					
	30 DAS	45 DAS	60 DAS	75 DAS	150 DAS	At Harvest
T_1 recommended spacing	5.2a	21.1b	41.9c	50.0ab	169.5bc	186.8b
T_2 Square planting	5.5c	22.0c	43.1d	49.3a	165.3a	186.4b
T_3 Skip row	5.3b	20.8b	41.4bc	50.5b	171.2c	190.2c
T_4 Low plant density	5.3b	22.2c	41.6bc	52.5c	168.7b	186.9b
T_5 High plant density	5.2a	21.3bc	40.9b	50.5b	165.4a	184.1a
T_6 Medium high plant density	5.3b	19.6a	39.5a	49.6ab	165.9a	184.2a
S.E.+	0.04	0.40	0.41	0.46	0.85	0.53
C.D @ 5%	0.08	0.84	0.85	0.96	1.76	1.09

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each stages of growth following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.2 Yield components and yield of maize

4.2.1 Number of cobs per plant.

Crop geometry differs significantly with respect to number of cob per plant at harvest all 6 different spacing as treatments and data represented in Table 4.13.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm) recorded significantly high cob $plant^{-1}$ (2.0) followed by (skip row planting) (1.9) as compared to (30cm x 15cm) high plant population density ha^{-1} (1.0).

With increase in plant population density ha^{-1}, there will be lesser the number of cobs per plant due to mutual shading of leaves low photosynthesis rate and lower availability of nitrogen, and water to the growing ear. If plant population dense there will be significantly decreased in number of cob per plant similar data was inline different experiment by Mahapatra *et al.* (2006), Mashiqa (2012) and Zheng (2009)

4.2.2 Weight of individual cob with husk (g)

Crop geometry differed significantly for individual cob weight with husk (g/cob) at harvest with all 6 different as treatments and data represented in Table 4.13.

Crop geometry low plant population density ha^{-1} (60cm x 30cm), recorded significantly high cob weight with husk (318.08 g cob^{-1}) followed by (skip row planting) plant 2 row followed by skip 1 row model (299.20 g cob^{-1}) as compared to (60cm x 20cm) recommended spacing (271.85 g cob^{-1}).

Due to lesser photosynthetic assimilation and dense population affected the weight of cob with husk these results are also in agreement with Kole (2010)

If plant population increased ha^{-1} low to high then there was decrease in the cob weight with husk similar result was obtained by different experiment Sikandar Azam *et al*., (2007), Mahapatra *et al.*, (2006), Zarapkar (2006) and Kunjir (2007)

4.2.3 Weight of Individual cob without husk (g)

Crop geometry differed significantly with respect of individual cob weight without husk (g) at harvest data presented in Table 4.13.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm), recorded significantly high cob weight without husk (222.94 g cob^{-1}) followed by (30cm x 30cm) square planting (215.80 g cob^{-1}) as compared to (60cm x 20cm) (212.17 g cob^{-1}).

Plant population increased ha^{-1} low to high result to decreased cob weight without husk because of inter specific competition between the plants which leads the cob diameter and length short if size of cob was less, weight of cob without husk low similar result was fined by Kunjir (2007) Similar work was done before and obtained similar data with different spacing by Mahapatra *et al.,* (2006), Sikandar Azam *et al*., (2007) Kole (2010).

4.2.4 Number of grains per cob

Crop geometry differs significantly with respect of number of grains cob^{-1} at harvest and data represented in Table 4.14.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm), found significantly high number of grains cob^{-1} (403.2) followed by skip row planting (planting 2 row followed by, 1 row skipping model), (401.4) as compared to high plant population density ha^{-1} (30cm x 15cm), (393.1)

At low plant population density decreases in barrenness low interplant competition for nutrient, moisture, space, resulted higher cob length, cob diameter and grains was high as compared to high plant population density.

Increase in plant population from low to high ha^{-1} and decreased spacing plant to plant and row to row then there was significantly reduction in number of grains per cob similar result was also expressed in different experiment by Bangarwn and Sannjiev (1997)

Table 4.13: Number of cob/plant, weight of individual cob with husk, weight of individual cob without husk influenced by crop geometry.

Treatment	Number of cob/plant	Cob wt. with husk (g)	Cob wt. without husk (g)
T_1 recommended spacing	1.6b	271.85a	212.17a
T_2 Square planting	1.8cd	278.00b	215.80c
T_3 Skip row	1.9d	299.20d	214.39b
T_4 Low plant density	2.0d	318.08e	222.94d
T_5 High plant density	1.0a	281.00c	213.20ab
T_6 Medium high plant density	1.5b	279.45bc	214.05b
S.E.+	0.03	0.89	0.58
C.D @ 5%	0.08	1.84	1.20

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for each yield parameter following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.2.5 Cob length (cm)

Crop geometry differs significantly with respect of cob length (cm) at harvest and data represented in Table 4.14.

Crop geometry low plant population density ha^{-1} (60cm x 30cm), recorded significantly high cob length (36.15 cm cob^{-1}) followed by (skip row planting) (35.54 cm cob^{-1}) as compared to recommended spacing (60cm x 20cm) (33.81cm cob-^{1}).

Plant population density and crop geometry effect on cob length at recommended spacing and high plant population density ha^{-1} found less cob length because of high plant competition.

Increased plant population ha^{-1} decreased the cob length (cm). Low plant population spacing of (60cm x 30cm) recorded higher cob length as this result are in conformity with the finding of Kanakdurga *et al*., (.2012) Similar results also find in different field experiment conducted by Thattil (1986), Baloyi (2013) and Fanadzo (2010) in maize.

4.2.6 Grain weight per plant (g)

Crop geometry and plant population density ha^{-1} was significantly differs with respect of grain weight $plant^{-1}$ at harvest and data represented in Table 4.14.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm) recorded significantly high grain weight $plant^{-1}$ (80.01 g $plant^{-1}$) followed by skip row planting (planting 2 row followed by skipping 1 row model),(65.42 g $plant^{-1}$) as compared to high plant population density ha^{-1} (30cm x 15cm) (54.54 g $plant^{-1}$).

Low plant population density ha^{-1} grain weight $plant^{-1}$ was high because of low interplant competition for photoperiod, available moisture and wider space is available in plant as compared to high plant population density. Plant population increased low to high significantly decreased per plant grain weight as per their crop under their conditions. Thavaprakaash and Velayudham (2013)

Table 4.14: Number of grains/cob, cob length (cm), grain weight/plant (g) influenced by crop geometry.

Treatment	Number of grains/cob	Cob length(cm)	Grain weight/plant(g)
T_1 recommended spacing	396.5bc	33.81a	63.56b
T_2 Square planting	398.2c	35.01ab	64.63c
T_3 Skip row	401.7d	35.54b	65.42c
T_4 Low plant density	403.2d	36.15b	80.01d
T_5 High plant density	393.1a	34.20a	54.54a
T_6 Medium high plant density	395.4b	34.50ab	62.75b
S.E.+	0.85	0.60	0.45
C.D @ 5%	1.75	1.24	0.94

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for yield parameter following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.2.7 Test Weight (g)/100 seed weight

Crop geometry significantly differs with respect of 100 seed weight at harvest and data represented in Table 4.15.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm) recorded significantly high 100 seed weight (24.80 g) followed by skip row planting (planting 2 row followed by skipping 1 row model), (24.1 g) as compared to (30cm x 15cm) high plant population density ha^{-1} (22.96 g).

Low plant population density ha^{-1} more availability of resources than the increasing photosynthetic rate for cob development resulted grain size was bold as compared to high plant population density ha^{-1} there is plant competition and grain size was small result to low 100 grains weight. Although increase in plant population per ha reduced the hundred grain weight. Skip row planting and square planting and (60cm x 30cm) obtained high 100 seed weight similar result obtained by Zarapkar (2006) and Kunjir (2007)

4.2.8 Grain yield (q/ha)

Crop geometry and plant population density ha^{-1} was showing significant results in respect of grain yield q ha^{-1} and data represented in Table 4.15.

Recommended spacing (60cm x 20cm) showing significantly high grain yield q ha^{-1} (58.11 q ha^{-1}) followed by T2: square planting (30cm x 30cm), (56.02 q ha^{-1}) as compared to T6: medium high plant population density ha^{-1} (60cm x 10cm), (49.50 q ha^{-1}).

At high plant population density ha^{-1} there was reduction yield components might be due to lesser photosynthetic rate and accumulation of lower assimilates which in turn decreased cob length, cob diameter and grain size which is directly responsible for low yield. In recommended spacing there is equal opportunity to all plant for growth and development which caused the higher grain yield ha^{-1}.

Increased plant population ha^{-1} significantly decreased the grain yield ha^{-1} this happen because of plant competition for space, sunlight, nutrient, moisture this result are in line with different experiment by Kanakdurga *et al*., (2012), Schlegel (2004), Ryan (2012) and Schlegel (2004)

4.2.9 Harvest index (HI%)

Crop geometry differed significantly with respect to harvest index and data represented in Table 4.15.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm) recorded significantly high harvest index (46.3 %) followed by T3: (skip row planting) planting 2 row followed by skipping 1 row model (44.6%) as compared toT5: high plant population density ha^{-1} (30cm x 15cm), (39.7%).

High plant population density ha^{-1} there is lower economic yield ha^{-1} and higher biological yield ha^{-1} result to reduction of harvest index as compared to low plant population density ha^{-1} there higher economic yield and lower biological yield result to intense harvest index (% ha^{-1})

Increase in plant population per ha from low to high led to significant reduction in harvest index. (30cm x 15cm) spacing per high plant population very high (2, 22,222) plant per ha then the harvest index recorded low as compared to low plant population per ha (60cm x 30cm) (55,555) plant per ha similar data was inline by Abraha (2013)

Table 4.15: 100 seed weight (g), grain yield q/ha^{-1}, harvest index (%) influenced by crop geometry.

Treatment	100 seed weight(g)	Grain yield q/ha^{-1}	Harvest index (%)
T_1 recommended spacing	23.16a	58.11f	42.5b
T_2 Square planting	23.50a	56.02e	43.7bc
T_3 Skip row	24.03c	54.17c	44.6c
T_4 Low plant density	24.80d	54.92d	46.3d
T_5 High plant density	22.96a	52.03b	39.7a
T_6 Medium high plant density	23.43b	49.50a	40.3a
S.E.+	0.06	0.27	0.50
C.D @ 5%	0.15	0.55	1.04

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for yield parameter following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.3 Nutrients status of soil

The data on available nitrogen, phosphorus, potassium status of soil kg ha^{-1} and organic carbon content (%) after harvest of maize data presented in Table 4.16.

4.3.1 Available Nitrogen (kg/ha) in soil

Crop geometry differs significantly with respect of available nitrogen in soil after harvest of maize and data represented in Table 4.16.

Crop geometry, low plant population ha^{-1} (60cm x 30cm) found significantly high nitrogen content in soil available after harvest (164.00 kg ha^{-1}) followed by square planting (30cm x 30cm), (163.33 kg ha^{-1}) as compared to high plant population density ha^{-1} (30cm x 15cm), (161.33 kg ha^{-1}).

At low plant population density ha^{-1} lower nutrient absorbed by plant than the available nutrient ha^{-1} was higher as compared to high plant population density ha^{-1} plant absorbed higher nutrient from soil and low available nutrient after harvest of crop.

Increased plant population density ha^{-1} recorded significantly lower nitrogen content in soil kg ha^{-1} and lower plant population density found high nitrogen content in soil similar data was in line with Thavaprakaash and Velayudham (2007), Waghmode (2010)

4.3.2 Available Phosphorus (kg/ha) in soil

Crop geometry differs significantly with respect to available phosphorus content in soil after harvest of maize and data represented in Table 4.16.

Crop geometry low plant population density ha^{-1} (60cm x 30cm), recorded significantly high phosphorus content in soil (22.15 kg ha^{-1}) followed by skip row planting (planting 2 row followed by skipping 1 row model),(21.14 kg ha^{-1}) as compared to high plant population density ha^{-1} (30cm x 15cm), (18.66 kg ha^{-1}).

High plant population density ha^{-1} there is high plant competition for nutrient and absorbs high nutrient from soil at time of crop growth than available nutrient content in soil was low as compared to low plant population density ha^{-1}.

Increased plant population per ha and decreased row to row distance respectively resulted in decreased phosphorus content in soil and similar findings are also in agreement with (Velayudhan *et al.*, (2013)

4.3.3 Available Potassium (kg/ha) in soil.

The crop geometry data revealed that, significantly higher potassium content in soil after harvest of maize and data represented in Table 4.16.

Spacing (60cm x 30cm) low plant population density ha^{-1} observed high available potassium kg ha^{-1} (323.55 kg ha^{-1}) followed by (skip row planting) (321.55 kg ha^{-1}) as compared to (30cm x15cm) observed low potassium content in soil (317.72 kg ha^{-1}).

High plant population density ha^{-1} higher vegetative growth of plant and more plant competition for nutrient, similarly absorbed higher potassium by plant from soil than available potassium content in soil kg ha^{-1} is low after harvest.

Increasing plant population density ha^{-1} respectively decreased phosphorus availability in soil after harvest similar finding was reveal by Agasibagil (2006)

4.3.4 Organic carbon (%)

Crop geometry differs significantly with respect of organic carbon in soil after harvest of maize and data represented in Table 4.16.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm) observed high organic carbon (0.47%) followed by square planting (30cm x 30cm), (0.46%) as compared to high plant population density ha^{-1} (30cm x15cm), (0.44%).

low plant population density ha^{-1} influenced organic carbon (%) in soil after harvest because at low plant population leaf maturation early and start drying mixing in soil which was correlated to increase organic carbon in soil, similar views were also expressed by Waghmode (2010)

Table 4.16: Nutrient content in soil (N, P, K) and organic carbon after harvest kg ha^{-1} influenced by crop geometry.

Treatment	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic carbon (%)
T_1 recommended spacing	162.33a	19.31a	318.37a	0.45b
T_2 Square planting	163.33c	20.12b	320.34b	0.46c
T_3 Skip row	163.00bc	21.14c	321.55b	0.45b
T_4 Low plant density	164.00c	22.15d	323.55c	0.47d
T_5 High plant density	161.33b	18.66a	317.72a	0.44a
T_6 Medium high plant density	162.00ab	19.14a	318.25a	0.45b
S.E.+	0.42	0.35	0.68	0.0046
C.D @ 5%	0.86	0.73	1.4	0.0095

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for available nutrient following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.4 Nutrient content in plant sample.

4.4.1 Nitrogen content in stem and leaves (N%)

Crop geometry significantly differs with respect of Nitrogen concentration in plant sample as higher nitrogen content in stem, leaves and data represented in Table 4.17.

Crop geometry of low plant population density ha^{-1} (60cm x 30cm), recorded significantly higher nitrogen concentration in plant (2.26 %) followed by skip row planting (planting 2 row followed by skipping 1 row model), (2.24%) as compared to recommended spacing of (60cm x 20cm), (2.19).

Wider spacing adequate moisture availability in soil due to less plant population pre m^{-2} less competition between plant to plant it results to influence the nutrient availability in soil and providing a pathway for nutrient transfer to the plant Velayudhan *et al*., (2013)

Increased plant population density ha^{-1} decreased nitrogen concentration in stem, leaves as compared to low plant population density ha^{-1} due to the lesser availability of soil nutrient suppress the plant growth and N concentration similar result obtained by Narayanappa *et.al.*, (2003) Plenet and Lemaire (2000) who stated increase areal biomass results to decreased N concentration of maize.

4.4.2 Phosphorus content in stem and leaves (P_2O_5%)

Crop geometry significantly differs with respect of phosphorus content in plant sample after harvest and data represented in Table 4.17.

Crop geometry of skip row planting (planting 2 row followed by skipping 1 row model), recorded higher nutrient concentration in leaves and stem (0.34%) followed by low plant population density ha^{-1} (60cm x 30cm), (0.33%) as compared to high plant population density ha^{-1} (30cm x 15cm), (0.30%).

Due to the higher plant population ha^{-1} non limiting nutrient available in soil resulted to lower nutrient content in plant sample. Narayanappa *et.al.*,(2003) found higher P concentration in davna crop at spacing of 45cm x 15cm (0.58%) and as compared to 45cm x 10cm (0.56%) sharing increased plant population lower to higher respectively decreased phosphorus concentration in plant sample.

4.4.3 Potassium content in stem and leaves (K_2O%)

Crop geometry significantly differs with respect of potassium concentration in stem and leaves of maize data presented in Table 4.17.

Crop geometry of low density planting (60cm x 30cm), recorded significantly higher potassium content in stem and leaves (2.24 %) followed by (60cm x 10cm) medium high plant population density ha^{-1} (2.23%) as compared to (60cm x 20cm) low plant population density ha^{-1} (2.18 %).

Medium plant population density ha^{-1} recorded low nutrient concentration in plant sample as compared to low plant population density ha^{-1} because medium plant population density number of plant m^{-2} was high then available potassium was low in plant sample, this result are in conformity with the finding of Narayanappa *et.al.*, (2003) and Dotaniya (2013)

Table 4.17: Nutrient content (%) in stem and leaves of maize influenced by crop geometry.

Treatment	N%	P%	K%
T_1 recommended spacing	2.19a	0.32b	2.18a
T_2 Square planting	2.25cd	0.31ab	2.22b
T_3 Skip row	2.2c	0.34c	2.19a
T_4 Low plant density	2.26d	0.33c	2.24c
T_5 High plant density	2.22bc	0.30a	2.22b
T_6 Medium high plant density	2.23bc	0.31ab	2.23bc
S.E.+	0.005	0.005	0.007
C.D @ 5%	0.014	0.013	0.015

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for nutrient content following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.5 Nutrient uptake (kg ha^{-1})

4.5.1 Nitrogen uptake (kg ha^{-1})

Crop geometry differs significantly with respect of nitrogen uptake by plant kg ha^{-1} data presented in Table 4.18.

High plant population density ha^{-1} (30cm x 15cm) observed higher nitrogen uptake (176.7 kg ha^{-1}) followed by medium high plant population density ha^{-1} (60cm x 10cm), (168.7 ka ha^{-1}) as compared to low plant population density ha^{-1} (60cm x 30cm) (143.9 kg ha^{1}.

At low plant population density recorded lower nutrient uptake by plant because of low dry matter production leading to lower uptake of N as compared to high plant population density ha^{-1} high dry matter production and more nutrient uptake kg ha^{-1}.

Increase in plant population ha^{-1} from low to high recorded significant increase in nitrogen uptake spacing (30cm x 15cm) recorded significantly high N uptake as compared low plant population ha^{-1} spacing (60cm x 30cm) similar finding was reveal by Thavaprakaash and Velayudham (2007)

4.5.2 Phosphorus uptake (kg ha^{-1})

Different plant population density ha^{-1} and crop geometry differs significantly with respect of phosphorus uptake kg ha^{-1} data presented in Table 4.18.

Crop geometry of high plant population density ha^{-1}(30cm x 15cm) recorded high phosphorus uptake (23.98 kg ha^{-1}) followed by medium high plant population density ha^{1} (60cm x 10cm),(22.82 kg ha^{-1}) as compared to low phosphorus uptake(60cm x 30cm) (19.68 kg ha^{-1}).

Increased plant population density ha^{-1} respectively increased dry biomass ha^{-1} (Stover yield ha^{-1}) result to influence the phosphorus uptake kg ha^{-1} as compared to low plant population density ha^{-1}.

Increase in plant population ha^{-1} from low to high recorded significant increase in phosphorus uptake spacing (30cm x 15cm) recorded significantly high P uptake as compared low plant population ha spacing (60cm x 30cm) similar data was inline by Velayudhan *et al*., (2013) and Thavaprakaash and Velayudham (2007)

Table 4.18: N, P, K uptake (kg/ha) in maize influenced by crop geometry.

Treatment	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
T_1 recommended spacing	167.01d	22.97d	164.14d
T_2 Square planting	160.13c	21.61b	157.88c
T_3 Skip row	149.17b	21.94b	145.73b
T_4 Low plant density	143.93a	19.69a	139.15a
T_5 High plant density	176.79f	24.32d	176.20f
T_6 Medium high plant density	168.76e	23.49c	166.52e
S.E.+	1.15	0.41	0.67
C.D @ 5%	2.37	0.85	1.38

T1 recommended spacing= 60x20cm, T2 square planting=30x30cm, T3 skip row planting= planting 2 row followed by 1 row skipping model, T_4 Low plant density= 60x30cm, T_5 High plant density=30x15cm, T_6 Medium high plant density. Value for nutrient uptake following different letter within each treatment are significant difference $P \leq 0.05$ % (Duncan's multiple range test).

4.5.3 Potassium uptake (kg ha^{-1})

Crop geometry and different plant population density ha^{-1} differs significantly with respect of potassium uptake and data represented in Table 4.18.

Crop geometry of high plant population density ha^{-1} (30cm x15cm) recorded significantly high potassium uptake (176.20 kg ha^{-1}) followed by medium high plant population density ha^{-1} (60cm x 10cm), (166.52 kg ha^{-1}) as compared to low plant population density ha^{-1} (60cm x 30cm), (139.15 kg ha^{-1}).

Increased plant population density ha^{-1} respectively increased dry biomass (Stover kg ha^{-1}) and result to high potassium uptake kg ha^{-1} as compared to low plant population density ha^{-1}.

Narrow spacing decrease leaf, stem and tassel dry matter production due to less availability of natural resources caused reduced vegetative growth of maize crop and N concentration of plant sample deficient range, this result in conformity with the finding of Agasibagil (2006), Velayudham *et al.*, (2013) and Thavaprakaash and Velayudham (2007).

5. SUMMARY AND CONCLUSIONS

A field experiment was conducted at Main Agricultural Research field, Lovely Professional University, Phagwara Punjab is situated in the (PB-3) Central Zone of the State Punjab on clayey loam soil to study "Impact of crop geometry on growth and yield of Maize (*Zea mays* L.) in Punjab alluvial soils" 2013. The experiment was laid out in Randomized Completely Blok Design (RCBD) there were 6 crop geometry *viz*., T_1 Recommended spacing (60cm x 20cm), T_2 square planting (30cm x 30cm), T_3 skip row planting (plant 2 row skip 1 row design),T_4 (60cm x 30cm), T_5 (30cm x 15cm),T_6 (60cm x 10cm). all six crop geometries were replicated thrice for statistical analysis.

Effect of crop geometry on growth parameters of (Zea *may*) Maize.

At all growth stage crop geometry, high plant population ha^{-1} (30cm x 15cm) recorded significantly taller plant and leaf area per plant followed by (60cm x 10cm). *i.e.,* (160.30cm) and 158.73cm at harvest respectively as compared to recommended spacing (60cm x 20cm) (146.87 cm). At 30 DAS higher leaf area per plant recorded at spacing of 30cm x 15cm, (101.0 cm^{-2}) followed by 60cm x 10cm, (98.2 cm^{-2}) which was better than recommended spacing of (60cm x 20cm) (91.1 cm^{-2}). Similarly number of green leaves per plant was significantly influenced due to spacing where 60cm x 10cm found higher number of green leaves at all growth stages followed by 30cm x 15cm or recommended spacing (60cm x 20cm).

Stem girth (cm $plant^{-1}$) all growth stages recorded significantly higher at spacing of (60cm x 30cm.) but if plant to plant spacing is narrow then significantly lower stem girth measured, (60cm x 10cm). Leaf area index (LAI) at overall growth stage higher leaf area index recorded at spacing (30cm x 15cm) higher plant population ha^{-1} as compared to recommended spacing (60cm x 20cm).

Crop geometry of square planting (30cm x 30cm) recorded significantly higher Absolute Growth Rate (AGR) at 45,60.,DAS and at harvest as compared to recommended spacing of maize(60cm x 20cm) but at 30,75,150 DAS skip row planting (plant 2 row and skip 1 row) recorded significantly higher AGR as compared to (60cm x 10cm).

Similarly spacing (60cm x 10cm) take more days for silking stage (116.3 DAS) as compared to skip row planting (plant 2 row and skip 1 row), *i.e.,* 106.3 DAS. Crop geometry differ significantly with respect to Crop growth rate (CGR), at all growth stages at harvest, high

CGR recorded at square planting (30cm x 30cm), (0.00588 $g/cm^{-2}/day$) as compared to (60cm x 10cm) (0.00485 $g/cm^{-2}/day$). Crop geometry square planting (30cm x 30cm), recorded significantly higher Net Assimilation Rate (NAR) at 30, 45, DAS and at harvest, as compared to recommended spacing of maize (60cm x 20cm).

Significantly higher total dry matter recorded at 30 DAS in square planting (30cm x 30cm) as compared to (30cm x 15cm) and recommended spacing (60cm x 20cm). At 150 DAS and at harvest, significantly high total dry matter recorded at skip row planting (planting 2,row followed by 1 row skipping model) as compared to (30cm x 15cm).

Effect of crop geometry on yield parameters of (Zea *may*) Maize

Crop geometry (60cm x 30cm) recorded significantly higher number of cob per plant, weight of individual cob with husk, and cob without husk as compared to recommended spacing (60cm x 20cm) or narrow spacing (30cm x 15cm) high population ha^{-1}.

Significantly high number of grain cob^{-1}, length of cob, grain weight $plant^{-1}$ was recorded at spacing (60cm x 30cm) low plant population ha^{-1} as compared to recommended spacing (60cm x 20cm) and spacing (60cm x 10cm).

Similarly thousand (1000) seed weight was higher at spacing (60cm x 30cm) (178.13 g) as compared to (30cm x 15cm) (161.43 g).

Significantly higher grain yield q ha^{-1} was recorded at recommended spacing of (60cm x 20cm) as compared to 60cm x 10cm or 30cm x 15cm. Skip row planting recorded highest harvest index (44.6%) as compared to (30cm x 15cm) (39.7%).

Effect of crop geometry on nutrient uptake by (Zea *may*) Maize.

Significantly higher nutrient concentration (NPK) of each plant sample was recorded at spacing of 60cm x 30cm as compared to recommended spacing of (60cm x 20cm) or after harvest Similarly, in soil higher NPK was recorded wider spacing (60cm x 30cm) (N-164 kg ha^{-1}),(P-22.15 kg ha^{-1}) and (K-323.55 kg ha^{-1}) as compared to narrow spacing (30cm x 15cm) (N-161.33 kg ha^{-1}),(P-18.66 kg ha^{-1}) and (K-317.72 kg ha^{-1}). And higher nutrient uptake was recorded at spacing (30cm x 15cm) higher plant population ha^{-1} as compared to skip row planting (plant 2 row, and skip 1 row) was recorded significantly lower nutrient uptake by Maize.

Conclusion

1) Higher vegetative growth of plant observed in higher density planting (30cm x 15cm).
2) High grain yield q ha^{-1} was recorded in recommended spacing (60cm x 20cm).
3) Chemical properties of soil NPK and organic carbon as residual fertility in soil after harvest was high in lower plant population density ha^{-1} (60cm x 30cm).
4) High NPK uptake was observed in in dense planting geometry (30cm x 15cm).

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APPENDIX

Appendix No 1: Details of biometric and other observations

Sr No	Particulars	Frequency	DAS	Plant per plot
I	**Growth Parameters**			
1.	Plant height (cm)	6	30,45,60,75,150,at harvest	5
2.	Number of green leaves per plant	6	30,45,60,75,150,at harvest	5
3.	Stem girth (cm)	6	30,45,60,75,150,at harvest	5
4.	Leaf area per plant (cm)	6	30,45,60,75,150,at harvest	5
5.	Leaf area index per plant (cm)	6	30,45,60,75,150,at harvest	5
6.	Days to Silking stage	1	After 100 Days	
7.	Absolute growth rate(g/plant/day)	6	30,45,60,75,150,at harvest	5
8.	Crop growth rate (g/cm^{-2}/day)	6	30,45,60,75,150,at harvest	5
9.	Net assimilation rate (g/cm^{-2}/day)	6	30,45,60,75,150,at harvest	5
10.	Total dry matter production	6	30,45,60,75,150,at harvest	3
II	**Yield Parameter**			
1.	Number of cob per plant	1	At harvest	5
2.	Weight of cob with husk	1	At harvest	5
3.	Weight of cob without husk	1	At harvest	5
4.	Number of grain per cob	1	At harvest	5
5.	Length of per cob (cm)	1	At harvest	5
6.	Grain weight per plant	1	At harvest	5
7.	Test weight (100 Seed g)	1	At harvest	5
8.	Grain yield (kg/ha)	1	At harvest	Net plot
9.	Harvest index (%)	1	At harvest	Net plot

Appendix No 2: Chemical analysis of Soil and Plant.

Sr. no	Particulars	Frequency	Days after Sowing	Method used
I.	**Soil Studies**			
1.	Available nitrogen in soil	2	Before sowing and at harvest	Micro kjeldahl method (Jackson, 1973)
2.	Available Phosphorus in soil	2	Before sowing and at harvest	Olsen's method. (Jackson , 1976)
3.	Available potassium in Soil	2	Before sowing and at harvest	Flame photometer method (Jackson,1973)
4.	pH and	1	Before sowing	pH meter (Piper, 1966)
5.	Electrical conductivity	1	Before sowing	Conductivity Bridge (Jackson, 1973)
6.	Organic carbon (%)	1	Before sowing and at harvest	Wet oxidation method (Jackson, 1973)
5.	Particle distribution (% Coarse sand, Fine sand, Silt and Clay content	1	Before sowing	International pipette method (Piper, 1966)
6.	Soil texture	1	Before sowing	International pipette method (Piper, 1966)
II.	**Plant analysis**			
1.	Nitrogen content in maize , leaves and stem of the plant	1	At harvest	Micro kjeldahl method (Jackson, 1973)
2.	Phosphorus content in maize, leaves and stem of the plant	1	At harvest	Vanado molybdate yellow colour method (Jackson,1973)
3.	Potassium content in maize, leaves and stem of the plant	1	At harvest	Flame photometer method (Jackson,1973)