Growth,productivity, available nitrogen,available phosphors, available potassium, available sulphurinfluencedby different plant spacing and nitrogen levels of Maize (*Zea mays* L.) in Bathinda districts of Punjab

Comment [RB1]: its should be little concise

ABSTRACT

A field experiment was conducted during (*Kharif*) seasons of 2023 at the Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, toeffectof different plant spacing and nitrogen levels on growth, productivity and available NPK of maize. The experiment was laid out in a split plot design with three replications, under three plant spacings of 45 cm x 15 cm, 55 cm x 20 cm, and 65 cm x 25 cm were included in the treatment plan, along with four nitrogen levels: control (75% of RDN (31.5 kg N/ha), 100% of RDN (42 kg N/ha), and 125% of RDN (52.5 kg N/ha). At every stage of the crop's growth, the leaf area index (LAI) with 125% of RDN was the highest and much better than that with 75% and 100% of RDN. Throughout the crop's growth stages, the spacing of 55 cm by 20 cm generated the least amount of dry matter. At a 45 cm X 15 cm spacing, the highest grain weight of 30.33 g was attained, which was comparable to the remaining plant spacing. At 55 cm X 20 cm, the lowest grain yield (52.76 q/ha^{-1}) was observed.With respect to nitrogen, highest harvest index (34.74%) was associated with application of 75% of RDN which was significantly superior over 100% of RDN With respect to plant spacing significantly highest harvest index (36.64%) was recorded at 45 cm X 15 cm and lowest harvest index (31.98%) was recorded with 65 cm X 25 cm and it was on par with 55 X 20 cm (33.24 %). With regard to plant spacing, higher soil available nitrogen and phosphorous was recorded at spacing of 65 cm X 25 cm, higher available potassium at spacing of 45 cm X 15 cm.

Comment [RB2]: season

Comment [RB3]: to find out / to investigate the effect

Comment [RB4]: first give main plots and then discuss sub plot

Keywords:Growth, productivity, available NPK, plant spacing, nitrogen levels, Maize.

INTRODUCTION

Maize (*Zea mays* L.)being one of the versatile emerging crop with wider adaptability under different agro-climatic environmental conditions. Around 1147.7 million metric tonnes of maize are produced worldwide from 193.7 million hectares, yielding an average of 5.75 tonnes per hectare in 170 countries with a variety of soil, climate, biodiversity, and management approaches (Meena and Nirupma, 2021). This amounts to 36% of grain production of the World. Because of its high level of genetic yield potential among all cereals, maize is known as 'Queen of Cereal's globally (Manjanagouda and Kalyanamurthy, 2018).The nutrients in cereals are distributed unevenly to have potential for reducing the risk of coronary heart disease, reducing tumour incidence, cancer risk, lowering blood pressure, reduced rate of cholesterol and fat absorption etc. Thus the diet with regular inclusion of cereals can contribute much to health promotion and disease prevention (Murdia*et al* 2016).

Maize (*Zea mays* L.), is a miraculous crop that is farmed for food and fodder because of its increased utility in agriculture and related industries.This crop has an advantage over other fodder crops because it may produce more green herbage, which is tasty, nutritious, succulent, sweet, and edible. It also has a lactogenic effect, and milch cows prefer it at any stage of the crop's growth.

Comment [RB5]: add more about the background of the study - related to nitrogen levels and plant spacing

Inadditiontonutrientmanagement,optimumplantpopulationalsoplay crucialroleinenhancementofcropproductivity.It isanestablishedfactthat higheryielddependsonoptimumplantpopulationandadequate nutrient application,particularlynitrogen.Also inrecentyears,hybridsofincreased tolerancetodifferentstresses,especiallyhighplantpopulationhavebeen released by genetic improvement (Tokatlidis and Koutroubas, 2004). Maize lacks tilleringcapacitytoadjustthelossoptimalcropstand.Optimum plantdensity should be characterized and maintained with uniform stand which is essential for higher and sustained productivity. Less than optimum plant population results in declinedproductivityduetoinefficientutilizationofresourcesbycrop.While excessive plantpopulationleadstosevereinter-plantcompetitionforbasic resources.

MATERIALAND METHODS

LOCATION OF THE EXPERIMENTAL SITE

WEATHER DURING THE CROP PERIOD

Its geographic coordinates are 208 meters above mean sea level and 29°57'38.3"N 75°07'20.3"E. The farm is located on the university's main campus.This region is well-known for its semi-humid climate, which features particularly severe summer and winter temperatures. A high of between 32.3 and 39.7degrees Celsius throughout the summer is not unusual. On the other hand, frost situations and freezing temperatures are possible in December and January. The monsoon usually starts in the first week of July.

Comment [RB6]: do not given general weather data, give specific data of kharif 2023

SOIL CHARACTERISTICS

When starting the experiment, the soil composition of the selected experimental plot was thoroughly examined, and a top 0–15 cm soil sample was taken from the experimental field before fertilizer was applied and the crop was planted. The material was crushed, air dried, and sieved through a 2 mm sieve before being chemically analyzed to ascertain the experimental site's inherent fertility. A comprehensive analysis of the soil's composition, including its texture, nutrient content, and moisture content, was done in order to understandthe Experimental Plot's soil profile, viz., pH-;Slightly Alkaline,Electrical Conductivity(ds/m) is Non-saline, Organic carbon is low, Available N is very low, Available P is low, Available K is medium, soil is sandy loam type

Comment [RB7]: give values

CROPPING HISTORY OF THE EXPERIMENTAL FIELD

The cropping history of experimental site shows that there has been a varied crop rotation over the years. Cereal crops like wheat and maize were cultivated extensively, and then, for research purposes, leguminous crops like lentils and chickpeas took over. Here is a summary of the last five years' crop history for the experimental field. The land has not received any organic fertilizer in the past when it came to cropping management.

Comment [RB8]: where is the summary of those crops, its missing

EXPERIMENTAL DETAILS; **Design and Layout**; Design: Split plot design; Number of treatments: 12; Number of replications: 3 Total number of plots: 36; Gross plot size: 4.5 m x 3.50 m = 15.75 m^2; Net Plot Size: 4.0 m x 3.0 m = 12.0 m^2 **Treatments**; Main plot: Plant spacing (3) S1:45 cm x 15 cm S2: 55 cm x 20 cm; S3: 65 cm x 25 cm; b) Sub plot: Nitrogen level (4); N1: Control (0 kg N/ha^{-1}) ; N2: 75% of RDN (31.5 kg N/ha^{-1}) ; N3: 100% of RDN (42 kg N/ha^{-1}) ;N4: 125 of RDN (52.5 kg N/ha^{-1})

Comment [RB9]: if possible give treatments in table

RESULTS AND DISCUSSION

The findings of the field study "**Effects of different plant spacing and nitrogen levels on growth and productivity of Maize (*Zea mays* L.)for Bathinda districts of Punjab**". The tests carried out during the Kharif season of 2023–2024 in the soil science laboratories of Guru Kashi University are presented in this chapter. It includes experimental data on several growth metrics, yield features and physico-chemical properties of the soil. Tables, conversations with relevant explanations present the data.

Comment [RB10]: was it a one year study or two ??

GROWTH PARAMETERS

The Bio-metric data on plant height, leaf area index and dry matter production were recorded at 30, 60 and at harvest intervals.

Plant Height

Plantheightofmaizemeasuredat30,60andat harvest hadnodifference duetodifferentlevelsofnitrogenandhoweveritdifferedsignificantlydueto different plant Spacing.

Comment [RB11]: mention table no. in the text related to the part

Comment [RB12]: 30, 60 DAS

The data showed that, up until 30 DAS, plant height climbed slowly; after that, it increased quickly until 60 DAS.The amount of nitrogen present at different growth phases did not significantly affect plant height. Although 125% of RDN generated higher plants (250.20 cm and 273.24 cm, respectively) at 60 DAS and at harvest, the other two treatments of Nitrogen levels (75% of RDN and 100% RDN) produced plants that were statistically comparable. The lack of response of the maize crop to plant height with three different nitrogen doses and one control could be the result of the plant's sufficient need for nitrogen for vegetative development at 125% of RDN. Ummed Singh *et al.* (2012) found comparable outcomes.

Plant height varied significantly due to plant spacing. At 60 and at harvest tallerplants259.97and282.55cm,respectively, wereproducedbyspacingof 65cmX25cmwhichwasstatisticallyatparwith55cmx20cmand significantlysuperioroverrestofthetreatmentstried.Atallthestagesofcrop growth the plant height produced with the inter row spacing of S1:45 cm x 15 cm and S2: 55 cm x 20 cm wasatparwitheachotherandwerehoweverlessthanwiththe treatments of inter row spacing of S3: 65 cm x 25 cm. Similar results were obtained by Narayanaswamy and Siddaraju (2011) and Ummed Singh *et al.*(2012).

Leaf Area Index

Plant spacing and varying N levels caused significant differences in the LAI of maize measured at different growth stages. Throughout the growing period, leaf area index (LAI) in maize rose significantly and gradually until harvest.

At all crop growth stages, the maximum leaf area index (LAI) was measured at 125% of RDN (1.55, 3.25, and 3.60 at 30, 60, and Harvest, respectively). This was noticeably better than 75% of RDN and 100% of RDN. At every stage of the crop's growth, the lowest leaf area index (LAI) was measured at 75% of RDN (1.31, 3.01, and 3.35 at 30, 60, and harvest, respectively), and it was comparable to 100% of RDN (1.44, 3.10, and 3.42 at 30, 60, and harvest, respectively). Applying nitrogen caused plants to develop more vigorously by raising the plant's leaf area index.Bangarwa and Gaur (1998), Shivay *et al.* (1999), Muniswamy*et al.* (2007), Suryavanshi *et al.* (2008), and Vinod Kumar *et al.* (2012) all reported similar outcomes.The leaf area index of the crop grew as plant spacing increased during all stages of crop growth. The highest LAI was seen at S3: 65 cm x 25 cm (1.40, 2.83, and 3.25 at 30, 60, and harvest, respectively), which was noticeably better than the other treatments.The S2 spacing of 55 cm x 20 cm at 30 (1.30) and harvest (3.24) was the location having the lowest LAI. Because there were more plants per unit area, the LAI increased as the number of plants increased.Sanjeev Kumar and Bangarwa (1998), Muniswamy*et al.* (2007), and Vinod Kumar *et al.* (2012) reported similar outcomes.

Comment [RB13]: 60 DAS

Comment [RB14]: table no ?

Comment [RB15]: DAS

Comment [RB16]: lowest was in control, not 75%

Comment [RB17]: check, explaination doesnot match with the data table

Dry matter accumulation

Drymatterproduction(gm^{-2}) showedincreasingtrendwiththe advancement of age of crop and reached maximum at 90 DAS. Increasing levels of nitrogen application significantly influenced the dry matter production (g m^{-2}) at all the stages ofcropgrowth. Application of125% of RDN wasfound significantly superior in dry matter accumulation by the crop at all the stages 30 (204.27 g m^{-2}), 60 (622.57 g m^{-2}) and 90 DAS (954.27 gm^{-2})over 75% of RDN and 100% of RDN.Nitrogenapplicationinducedthevigorousgrowthofplantsby increasingleafnumberandLAI,whichmightbeduetohigherphotosynthetic activityofplant,therebyproducingmaximumdrymatter.Similarresultswere observed by Bangarwa and Gaur (1998), Shivay *et al.* (1999), Muniswamy*et al.* (2007), Suryavnshi*et al.* (2008) and Vinod Kumar *et al.* (2012).

Comment [RB18]: table no.

In terms of plant spacing, the spacing of S1:45 cm x 15 cm at 60 (680.40) and 90 (1059.28) DAS and S3: 65 cm x 25 cm at 30 DAS (216.04), which was comparable with S1:45 cm x 15 cm at 30 DAS (206.31), provided the considerably largest dry matter (g m^{-2}). The crop produced the least amount of dry matter at S2 spacing, which was 55 cm by 20 cm, during all growth stages (176.17, 553.40, and 836.05 30, 60, and 90 DAS, respectively).More plants per unit area was the cause of the rise in dry matter output that accompanied an increase in plant density. Muniswamy*et al.* (2007) and Sanjeev Kumar and Bangarwa (1998) both reported similar outcomes.

Comment [RB19]: rewrite

DEVLOPMENT STUDIES

Tasseling Stage (50%) AndSilking Stage (50%)

Comment [RB20]: explanation missing

Both nitrogenand plant spacing levelsshowedsignificantinfluenceon days to 50 per cent silking in maize.

Comment [RB21]: table no

Thenumberofdaystakenbythecroptoreach50percentsilkingstage decreasedwithincreaseinnitrogenlevelupto125% of RDN.Maize fertilized with higher dose of N (125% of RDN) took significantly less number of days to 50percentsilking(51.61)followedby100% of RDN(52.05), 75% of RDN (53.00)andcontrol (53.23). Similar results were observed byJacobs and Pearson (1991), Muniswamy*etal.* (2007) and Vinod Kumar *et al.* (2012).Reducing the plant spacing to an S3 of 65 cm × 25 cm resulted in a much shorter time (51.44) to reach 50% silking stage. Low plant density increased the amount of food materials that were transferred from the source (leaf) to the sink (reproductive portions). Because there was less competition among the plants at low densities, the plants grew vigorously and produced silking earlier. Similar findings, namely a

Comment [RB22]: its increasing, not reducing delay in silking as a result of dense planting, were noted by Vinod Kumar *et al.* (2012), Muniswamy*et al.* (2007), and Jacobs and Pearson (1991).

Per cent Barren plants

Thedatarecordedonpercentbarrennessrevealedthatthere was a significant difference due to planting densities and nitrogen levels. Per centbarrennessrecorded wassignificantlylowerat65 cm x 25 cm (1.42)thanat 55 cm x 20 cm (1.85) and 65 cm x 25 cm (2.16). More barrenness at high densitieswas duetotheabsenceoftheusualsinkfortheassimilatesupplyand limitingoptimumconversionoflightenergyto grain inmaizecropwhich inhibited the plants to produce viable ears. This trend of increase in barren plants inresponsetoincreasedplant populationwasalsoreportedbySahooand Mahapatra (2007) and Dawadi and Sah (2012).

Comment [RB23]: table no. and explanation of sub plots is missing

STUDIES AT HARVEST

Final plant population (no.)

Data recorded on initial and final plant population of maizeindicatedthatinitial plant populationwasmaintainedasperthe treatments and there was a very slight variation in the final plant population which is negligible.

Comment [RB24]: what was the reason for variation in rhe population ?

length of cob (cm)

Due to varying N levels, maize cob length varied significantly and was not statistically discernible from variation in plant spacing.The maximum length of a cob (16.82 cm) was measured at 100% of RDN, which was considerably longer than the control (14.12 cm) and 75% of RDN (16.02 cm). It was also on par with 125% of RDN (16.02 cm).

Comment [RB25]: not clear

The length of the maize cob was not significantly impacted by plant population numbers. The longer cobs (16.53) were seen at S3 spacing, which is 65 cm x 25 cm, and this spacing was comparable to the other spacings.The cob with the smallest length 15.45 cmwas measured at an interval of S1:45 cm by 15 cm.Narayanaswamy and Siddaraju (2011) found similar outcomes.

Diameter of cob (cm)

Thedatapresentedrevealedthatnitrogenlevelsmarkedly influencedthecobdiameter ofmaize,whereasplantdensityhadnoeffectoncob diameter.

Comment [RB26]: table number

Cob diameter increased with increased levelsofnitrogen. The cob diameter was significantly highest with N level of 125% of RDN. The plant population levels could not show significant effect on cob 125% of RDN of maize. The maximum cob diameter (13.83 cm) was associatedwith plant spacing S3: 65 cm x 25 cmandtheminimumgirthwasfound(13.65 cm)at spacing of S1:45 cm x 15 cm. Similar results was obtained by Narayanaswamy and Siddaraju (2011).

Number of grains per cob

Perusal of thedata onnumberofgrainscob^{-1} revealedthat the number of grainscob^{-1} was significantly influenced by planting spacing and nitrogen levels. Maximumnumberofgrainscob^{-1} wasrecordedwith 65 cm x 25 cm (412.4) whichwassignificantlysuperiorto 55 cm x 20 cm (364.8) and 45 cm x 15 cm (298.7).

Increasing thenitrogenlevel from control to 75% of RDN, 100% of RDN and 125% of RDN increasedthe numberofgrainscob^{-1}. The highestnumberofgrainscob^{-1} (367.4) was obtained with 125% of RDN, significantlysuperiorto allthe otherlevels ofnitrogen.Theincreasednitrogensupplyandreducedplantdensityenhanced thenumberofcobs perplantasreportedbyTariqMahmoodandMuhammad Saeed (1998) and Hari Om *et al.* (2014).

Grain yield per cob (g)

Marked differences ofGrain weightwererecordedduetovariationsin nitrogen application from control to 125% of RDN. Significantly highest grain weight (126.6g) was recorded with 125% of RDN which was on par with 100% of RDN (123.0 g) alone and 75% of RDN (119.2 g). The maximum grain weight recorded mightbeduetoproperavailabilityofnitrogen fertilizerwhichhelpedtheplanttoutilizethenutrientswiththeirmaximum potentialofuptake. Thesefindingsareincloseconformitywiththeearlier findings of Sekhar *et al.* (2012) and Hari Om *et al*. (2014). Increase in grain weight might have favoured moreabsorptionof nutrients to hybrid maize. These results areinagreementwithParasuraman (2006)andPotarzycki and Grebisz (2009).

100-grain weight (g)

Thehundredseedweightwassignificantlyinfluencedbynitrogenlevels but plantspacing exertanysignificant influence on hundred seed weight.

As the amount of nitrogen increase from zero (control) to 125% of RDN, the weight of a hundred maize seeds increased significantly. Compared to the control, 75% of RDN, 100% of RDN, and 75% of RDN, the greater hundred seed weight (30.61g) obtained with 125% of RDN was substantially superior. Bangarwa and Gaur (1998), Shivay *et al*. (1999), Muniswamy*et al.* (2007), Suryavanshi *et al.* (2008), and Vinod Kumar *et al.* (2012) all reported similar results.

Grain Yield (q/ha^{-1})

Thegrainyieldofmaizewassignificantlyinfluencedbynitrogenlevels andnotstaticallyinfluencedbytheplantspacing.Highest grainyield of maize (63.13 q/ha^{-1}) was

Comment [RB27]: main plot is not explained

Comment [RB28]: grain

Comment [RB29]: rewrite

Comment [RB30]: check

Comment [RB31]: table number

Comment [RB32]: cross check with data table recorded with 125% of RDN anditwassuperiorwithrestofthetreatmentsof control, 100% of RDN and 75% of RDN,respectively. Similarresultswereobservedby Muniswamy*etal*. (2007),Suryavanshi *etal*., (2008)andVinodKumar *etal*. (2012).Thegrainyieldofmaizewasnotvariedduetoplant Spacing.However, the highest grain yield (62.62 q/ha^{-1}) was recorded at a spacing of S3: 65 cm x 25 cm anditwasonparwithallthespacingstriedexcept45 cm x 15 cmwhich recordedlowestgrainyield(52.76 q/ha^{-1}).Similar resultswereobtainedby Chennakesava*et al*. (2000) and Suryavanshi *et al*. (2009).

Stover Yield (q/ha^{-1})

In table showed that differences in plant population levels and nitrogen content that caused significant variations in maize stover yield. Applying higher N levels considerably boosted the stover production. The amount of stover yield (90.61 q/ha^{-1}) that was produced by maize fertilized with 125% RDN was much higher than that of 100% RDN, but it was still significantly higher than that of 75% RDN and control.The treatment under control yielded the lowest stover output, measuring 54.90 q/ha^{-1}.Bangarwa and Gaur (1998), Shivay *et al*. (1999), Muniswamy*et al*. (2007), Suryavanshi *et al*. (2008), and Vinod Kumar *et al*. (2012) all reported similar outcomes.The plant spacing showed significant effect on stover yield of maize. The highest stover yield (88.78 q/ha^{-1}) was obtained with 65 cm x 25 cm and the lowest stover yield (68.78 q/ha^{-1}) obtained at 45 cm X 15 cm.

Harvest index (%)

Harvest index of maize was significantly influenced by nitrogen level and plant spacing. Withrespecttonitrogen,highestharvestindex(34.74 %)wasassociated with application of 75% of RDN which was significantly superior over control, 100% of RDN and 125% of RDN,lowestharvestindex(27.45 %)wasobservedwith control treatment. With respect to plant spacing significantly highest harvest index (36.64 %) was recorded at 45 cm X 15 cm and lowest harvest index (31.98 %) was recorded with 65 cm X 25 cm and it was on par with 55 cm X 20 cm (33.24 %).

SOIL STUDIES

Chemical properties

Post harvest soil available Nitrogen

Datapertainingtopostharvestsoilavailablenitrogenasinfluencedby differentlevelsofnitrogenandplantspacing. Post harvest soil available nitrogen status was significantly influenced by differentlevelsofnitrogenandnotstaticallyinfluencedbytheplantspacing.

Comment [RB33]: no. ?

Comment [RB34]: justification of results is missing

Comment [RB35]: how harvest index was calculated ? it need to be cross checked once.

With crop harvest, there was more soil accessible nitrogen with higher amounts of nitrogen than earlier. The maximum amount of nitrogen studied, or 125% of RDN, was found to be soil accessible nitrogen (296.1 kg/ha^{-1}), which was noticeably more than 100% of RDN (266.33 kg/ha^{-1}).Increased mineralization driven on by more nitrogen fertilization may be the cause of an increase in post-harvest soil accessible nitrogen.Similar results were attained by Paramasivan and associates (2011).

The postharvest soil available nitrogen was not significant varied due to plant spacing. However,thehighestavailablenitrogen(286.77 kg/ha^{-1})wasrecordedata spacing of 55cm X 20 cm and it was on par with all the spacings tried except 45cm X 15cm which recorded lowest available nitrogen (260.33 kg/ha^{-1}).

Post harvest soil available Phosphorous

Data pertaining to post harvest soil available phosphorous as influenced by differentlevelsofnitrogenandplantspacingispresentedin Table. Post harvest soil available phosphorous status was significantly influenced by different levels of nitrogen and not statically influenced by the plant spacing. Regardingdifferentlevelsofnitrogen,higherpostharvestsoilavailable phosphorus was associated with the application of 75% of RDN (118.75 kg/ha^{-1}) which was significantlysuperior to 125% of RDN (92.04kg/ha^{-1}),while lower availablephosphorouswasrecordedwiththeapplicationof125% of RDN (92.04kg/ha^{-1}).

Available phosphorus decreased with increase in nitrogen level. Thiswasprobablyduetopositiveinteractionofphosphoruswithincreased nitrogenapplicationi.e.theacidifyingeffectofaddednitrogenfertilizer enhancingthephosphorussolubility,therebyincreasingtheavailabilityof phosphorusandresultinginlessavailablephosphorusafterharvestathighest nitrogen levels. Thepostharvestsoilavailablephosphorouswasnotvariedduetoplant spacing.

Post harvest soil available Potassium

Tablepresents the findings on post-harvest soil accessible potassium as impacted by nitrogen levels and plant spacing. In terms of nitrogen levels, the application of 75% of RDN (431.32 kg/ha^{-1}) compared to 125% of RDN (340.67 kg/ha^{-1}) resulted in noticeably higher post-harvest accessible soil potassium, while the application of 125% of RDN (340.67 kg/ha^{-1}) resulted in the lowest levels. Potassium likewise exhibited the same trend as phosphorus, meaning that it had a positive interaction with nitrogen, increasing its availability during crop growth and resulting in less potassium being accessible after harvest at higher nitrogen levels.

Comment [RB36]: no. ?

Comment [RB37]: add reference

Comment [RB38]: no.?

Comment [RB39]: if same level of potassium is applied, how it is possible that it is significant after the harvesting of crop ??

The plant densities showed significant effect on available potassium. The highest available potassium (404.88 kg/ha^{-1}) was recorded with 55 cmX 20 cm and the lowest available potassium (331.52 kg/ha^{-1}) was found at 45 cm X 15 cm which was on par with 55 cm X 20 cm and 65 cm X 25 cm.

Comment [RB40]: reason and justification

Post harvest soil available Sulphur

Data on postharvest soil that is accessible showed that influence of varying nitrogen levels and plant spacing on sulfur levels. Accessible post-harvest soil different nitrogen levels had a substantial impact on sulfur status, although plant spacing had no statistically significant effect.

Comment [RB41]: check

Comment [RB42]: sulphur

With crop harvest, there was more soil accessible sulphur with higher amounts of sulphur than earlier. The maximum amount of sulphur studied, or 125% of RDN, was found to be soil accessible sulphur (5.03 kg/ha^{-1}), which was noticeably more than 100% of RDN (4.98 kg/ha^{-1}).Increased mineralization driven on by more nitrogen fertilization may be the cause of an increase in post-harvest soil accessible ulphur. Similar results were attained by Paramasivan and associates (2011).

The postharvest soil available sulphur was not significant varied due to plant spacing. However,thehighestavailable sulphur (4.76 kg/ha^{-1})wasrecordedata spacing of 65cm X 25 cm and it was on par with all the spacing treatments.

Table 1: -Influence of plant spacing and nitrogen levels on plant height (cm) of maize

Treatment	Days after Sowing		
	30	**60**	**At Harvest**
S1:45 cm x 15 cm	76.13	244.71	272.10
S2: 55 cm x 20 cm	77.28	237.17	264.14
S3 : 65 cm x 25 cm	81.82	259.97	282.55
SEm±	0.73	2.26	0.05
CD 5%	3.20	9.72	7.39
N1: Control	66.42	200.54	250.78
N2: 75% of RDN	77.53	242.73	269.77
N3: 100% of RDN	77.87	250.67	275.46
N4: 125% of RDN	79.85	250.20	273.24
SEm±	0.49	1.67	1.35
CD 5%	NS	NS	NS

Table 2: -Influence of plant spacing and nitrogen levels on leaf area index of maize

Treatment	Days after Sowing		
	30	**60**	**At Harvest**
S1:45 cm x 15 cm	1.74	3.71	4.02
S2: 55 cm x 20 cm	1.30	2.93	3.24
S3 : 65 cm x 25 cm	1.40	2.83	3.25
SEm±	0.006	0.014	0.014
CD 5%	0.03	0.04	0.04
N1: Control	0.92	2.61	2.90
N2: 75% of RDN	1.31	3.01	3.35
N3: 100% of RDN	1.44	3.10	3.42
N4: 125% of RDN	1.55	3.25	3.60
SEm±	0.006	0.006	0.006
CD 5%	0.02	0.03	0.03

Table 3: - Influence of plant spacing and nitrogen levels on dry matter accumulation (g m^{-2}) of maize

Treatment	Days after Sowing		
	30	**60**	**90**
S1:45 cm x 15 cm	206.31	680.40	1059.28
S2: 55 cm x 20 cm	176.17	553.40	836.05
S3 : 65 cm x 25 cm	216.04	608.03	928.11
SEm±	3.41	4.72	4.45
CD 5%	9.82	13.58	12.82
N1: Control	119.43	409.23	675.09
N2: 75% of RDN	162.84	512.34	830.02
N3: 100% of RDN	186.39	594.16	869.57
N4: 125% of RDN	204.27	622.57	954.27
SEm±	2.41	3.33	3.15
CD 5%	6.94	13.58	9.06

Table 4: -Influence of plant spacing and nitrogen levels on days to 50% tasseling stage, days to 50% silking stage and% barren plants of maize crop.

Treatment	Days to 50 %		% Barren plants
	Tasseling stage	Silking stage	
S1:45 cm x 15 cm	**58.03**	**52.88**	**2.16**
S2: 55 cm x 20 cm	**57.90**	**51.55**	**1.85**
S3 : 65 cm x 25 cm	**56.31**	**51.44**	**1.42**
SEm±	**1.00**	**0.24**	**0.042**
CD 5%	**NS**	**0.72**	**0.16**
N1: Control	**48.23**	**43.23**	**2.40**
N2: 75% of RDN	**59.03**	**53.00**	**2.15**
N3: 100% of RDN	**58.34**	**52.05**	**1.98**
N4: 125% of RDN	**57.19**	**51.61**	**1.49**
SEm±	**1.50**	**0.17**	**0.061**
CD 5%	**NS**	**0.50**	**0.17**

Table 5: - Influence of plant spacing and nitrogen levels on plant population, length of cob, diameter of cob and number grains per cob of maize crop

Treatment	Length of cob	Diameter of cob	Number grains per cob	100-grain weight (g)
S1:45 cm x 15 cm	15.45	13.65	298.7	30.33
S2: 55 cm x 20 cm	16.35	13.66	364.8	28.88
S3 : 65 cm x 25 cm	16.53	13.83	412.4	26.11
SEm±	0.30	0.10	9.03	0.79
CD 5%	0.89	0.31	35.4	2.28
N1: Control	14.12	11.45	256.7	26.12
N2: 75% of RDN	16.02	13.51	298.1	26.50
N3: 100% of RDN	16.82	13.63	329.8	28.72
N4: 125% of RDN	16.18	13.90	367.4	30.61
SEm±	0.21	0.07	12.93	0.55
CD 5%	0.63	0.55	36.9	1.61

Table 6: - Influence of plant spacing and nitrogen levels on grains yield per cob (g), 100-grain weight (g), grain yield (q/ha^{-1}), stover yield (q/ha^{-1}), harvest yield (%) of maize crop.

Treatment	Grains yield per cob (g)	Grain yield (q/ha^{-1})	Stover yield (q/ha^{-1})	Harvest index (%)
S1:45 cm x 15 cm	124.4	61.74	68.78	36.64
S2: 55 cm x 20 cm	127.0	52.76	70.58	33.24
S3 : 65 cm x 25 cm	133.1	62.62	88.78	31.98
SEm±	2.56	2.81	2.26	1.27
CD 5%	NS	8.27	6.51	3,59
N1: Control	109.9	30.56	54.90	27.45
N2: 75% of RDN	119.2	51.70	62.48	34.74
N3: 100% of RDN	123.0	56.53	90.38	31.32
N4: 125% of RDN	126.6	63.13	90.61	30.06
SEm±	4.31	20.45	1.60	0.9
CD 5%	11.3	5.65	4.61	2.51

Comment [RB43]: calculate the data again and analyse

Comment [RB44]: check

Table 7: - Influence of spacing and nitrogen levels on Available nitrogen (Kg ha^{-1}), Available Phosphorus (Kg ha^{-1}), Available potassium (Kg ha^{-1})and Available Sulphur on postharvest available soil nutrients.

Treatment	Available nitrogen (Kg ha^{-1})	Available Phosphorus (Kg ha^{-1})	Available potassium (Kg ha^{-1})	Available Sulphur
S1:45 cm x 15 cm	260.33	102.36	331.52	3.84
S2: 55 cm x 20 cm	286.77	119.71	404.88	4.02
S3 : 65 cm x 25 cm	273.55	104.58	344.46	4.76
SEm±	10.93	7.45	17.11	0.25
CD 5%	NS	NS	83.68	1.19
N1: Control	186.09	72.09	256.89	3.06
N2: 75% of RDN	259.38	118.75	431.32	3.12
N3: 100% of RDN	266.33	101.92	399.44	4.98
N4: 125% of RDN	296.11	92.04	340.67	5.03

SEm±	6.80	5.68	20.58	0.37
CD 5%	23.02	16.21	59.17	1.12

Comment [RB45]: proper justification and reference for this need to be added

Comment [RB46]: add reason and justification as how different plant spacing can influence the available potassium significantly?

SUMMARY AND CONCLUSION

Afieldexperimentwasconductedduring kharif,2024onsandyloam soilsofGuru Kashi University, situated in Talwandi Sabo, Bathinda,tostudythe"Effects of different plant spacing and nitrogen levels on growth and productivity of Maize (*Zea mays* L.) for Bathinda districts of Punjab". Theexperiment was laid out in Split Plot Design and replicated thrice. The treatments consisted of four nitrogen levels viz., N1-Control (0 kg N/ha^{-1}), N2-75% of RDN (31.5 kg N/ha^{-1}), N3-100% of RDN (42 kg N/ha^{-1}) and N4-125% of RDN (52.5 kg N/ha^{-1}) and three plant spacing, viz.,S1-45 cm x 15 cm, S2- 55 cm x 20 cm and S3- 65 cm x 25 cm. The salient findings of the investigation are summarized below. Observationswererecordedongrowthparameters viz.,plantheight,leafarea index,drymatterproductionanddaysto50percentsilkingandyieldandyield attributes viz., cob length, cob girth, number of rows per cob, number of grains per row,100grainweight,grainyieldandStoveryield.Datawasalsocollectedon shellingpercentage,harvestindex,postharvestavailableN,P,Kstatusofthesoil for different treatments.

All the above mentioned parameters of maize were influenced by graded levels of nitrogen and plant spacing. At 60 DAS and at Harvest taller plants (250.67 cm and 275.46 cm, respectively) were produced by 125% of RDN which was however statistically at par with the other two treatments of100% of RDNand75% of RDN. At60 DAS and At harvest tallerplants(259.97 and 282.55 cm, respectively) were produced by a spacing of 65 cm X 25 cm which was statisticallyatparwith55 cmX20 cmandsignificantlysuperioroverrestofthe treatments tried. Thehighestleafareaindex(LAI)was recordedwith125% of RDN,which was significantly superior over 75% of RDN and 100% of RDN at all the growth stages of the crop.Thelowestleafareaindex(LAI)wasrecordedwith75% of RDN atallthe growth stages of the crop and was on par with control. The highest LAI was recorded at a spacing of 45 cm X 15 cm at all the stages of crop growth. The lowest LAI was recorded at spacing of 55 cm X 20 cm at all the stages of crop growth. Application of 125% of RDN was found significantly superior and increased thedrymatteraccumulationbythecropatallstagesof30(204.27g m^{-2}),60 (622.57 g m^{-2}) and 90 DAS (954.27 g m^{-2}) over 100% of RDN, 75% of RDN and control. The highest dry matter (g m-2) was produced at a spacing of 65 cm X 25 cm at 60 and 90 DAS andwith55cmX20cmat30DASwhichwasonparwith45cmX15cmat30 DAS.Thelowestdrymatterwasproducedatspacingof55cmX20cmatall growthstagesofthecrop. Application of higher dose of N (125% of RDN) took significantly less number of days to 50 per cent silking (57.19) followed by 100% of RDN (58.34) and 75% of RDN (53.00). Lower plant spacing with a spacing of 65 cm X 25 cm had taken less number of days(51.44)toreach50percentsilkingstageandhigherplantdensitywitha spacing of 45 cm X 15 cm and 55 cm X 20 cm took maximum days (52.88). The highest cob length (16.82 cm) was recorded at 100% of RDN which was significantly superior over 75% of RDN (16.02 cm) and was at par with 125% of RDN (16.18 cm). The longer cobs (16.53 cm) were observed at a spacing of 65 cm X 25 cm and it was on par with rest of different spacing. The lowest cob (15.45 cm) length was recorded at a spacing of 45 cm X 15 cm. Thecobgirthwassignificantlyhighestwith N levelof125% of RDN.The maximum cob girth (13.66 cm) was associated with lower plant density i.e.55 cm X 20 cm and the minimum girth was found (13.65 cm) at spacing of 45 cm X 15 cm. Thehundredseedweight(30.61g)obtainedwith 125% of RDN was significantlysuperiorover100% of RDN and75% of RDN.The maximum hundredgrain weight (30.33 g) was obtained at a spacing of 45 cm X 15 cm and it was on par with rest of the plant spacing. The highestgrain yield(63.13 q/ha^{-1})wasrecordedwith125% of RDN which was significantly superior to 100% of RDN and was at par with 75% of RDN.

The lowest grain yield (30.56 q/ha^{-1}) was recorded on control treatment. The highest grain yield (62.62 q/ha^{-1}) was recorded with the spacing of 65 cm X 25 cm.The lowest grain yield (52.76 q/ha^{-1}) was recorded at 55 cm X 20 cm. With respect to nitrogen, highest harvest index (34.74%) was associated with application of 75% of RDN which was significantly superior over 100% of RDN and control and lowestharvestindex(30.06 %)wasobservedwith125% of RDN.With respect to plant spacing significantly highest harvest index (36.64 %) was recorded at 45 cm X 15 cm and lowest harvest index (31.98%) was recorded with 65 cm X 25 cm and it was on par with 55 X 20 cm (33.24 %). Maize fertilized with 125% of RDN produced significantly more stover yield (90.61 q/ha^{-1})butitwasonparwith100% of RDN andsignificantlysuperior over 75% of RDN. The lowest stoveryield (54.90 q/ha^{-1}) was with application of no nitrogen (control) treatment. The highest stover yield (88.78 q/ha) was obtained with 65 cm X 25 cm and the lowest stoveryield (68.78 q/ha^{-1}) obtained at 45 cm X 15 cm. As regards to post harvest soil nutrients, available nitrogen was increased with increasinglevelsofnitrogenfrom75% of RDN to 125% of RDN andmaximumsoilavailable phosphorusandpotassiumwererecordedwithapplicationof75% of RDN.The minimum soilavailablephosphorusandpotassiumwererecordedwithapplication of 125% of RDN, with regard to plant spacing, higher soil available nitrogen and phosphorous was recorded at spacing of 65 cm X 25 cm, higher available potassium at spacing of 45 cm X 15 cm. The lowest soil available nitrogen was recorded at spacing of 45 cm X15cmandlowestsoilavailablephosphorousandpotassiumwasrecordedat45 cm X 15 cm.

Comment [RB47]: give conclusion of the study in just 5-7 lines, mentioning the key output of the study and what can be inferred from this study?

Comment [RB48]: few reference can be added from latest paired row planting as lesser spacing is followed there, which might be used for justification of lower yield in the closer spacing ?

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