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Effect of plant spacing and date of sowing on yield and yield attributes of popcorn (*Zea mays* everta) under rainfed conditions of valley

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Abstract
Two field experiments were conducted at DARS Budgam, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during 2016 and 2017 under rainfed conditions with the objective to study the growth and yield of popcorn at different sowing dates, plant spacing and nitrogen levels. Experiment was laid in split-split plot design assigning three Sowing Dates 19th Standard Metrological week (May 02-May 08) (D_1), 21th Standard Metrological week (May 16-May 22) and 23nd Standard Metrological week (May 30-June 05). Two plant spacings where maintained viz: S_1i.e 60cm X 20cm (83000 plants ha^{-1}) and S_2 i.e. 60cm X 15cm (104166 plants ha-^{1}) along with three nitrogen levels viz: N_1 =90 kg ha^{-1} $_{N2}$ =120 kg ha^{-1} and N_3=150 kg ha^{-1}. The results revealed that grain and stover yield of maize increased significantly for maize sown in 21th standard meteorological week with concomitant increase in its yield attributes viz., cob length, cobs per plant, no. of grains per cob and 100-grain weight and growth characters like plant height, number of leaves per plant, leaf area index and dry matter accumulation which had longer vegetative phase than late planting dates for both the years. Among planting density, 60cm×20cm (S_1) recorded significantly higher grain yield (3.48 and 3.73 ton ha^{-1}) and stover yield (5.76 and 6.12 ton ha^{-1}) for the year 2106 and 2017 respectively. Growth and yield attributing characters also recorded highest value with planting density 60cm×20cm (S_1). Popping percentage recorded for plant spacing S_1 (60cm×20cm) was statistically superior as compared with same of S_2 (60cm×15cm). As far as Nitrogen levels are concerned, growth characters like plant height, total number of leaves per plant, dry matter accumulation increased significantly with 120kg/ha nitrogen. Also grain and stover yield showed significant and consistent improvement with increased dose of nitrogen (120 kg/ha). Yield attributing characters showed significant improvement with increasing the level at 150kg/ha. Also popping percentage and nutrient content of plant at anthesis and grain was significantly higher for 150kg/ha nitrogen whereas popping volume and nitrogen content in stover was statistically at par with respect to three nitrogen levels.

Keywords: Standard meteorological week, sowing dates, plant spacing, popping percentage, popping volume, yield attributes, and yield

Introduction
Popcorn (*Zea mays* var. everta) is type of corn grown in small acreage around the urban area. The ability to pop is the unique characteristic that distinguishes from other types of corn. The grains of popcorn are small pointed with honey or hard endosperm. The endosperm has more hard starch compared to soft starch. The difference in popping character of dent corn and popcorn is that, relatively higher soft endosperm of the dent or flour corn with fragile cell walls allow the steam generated during the application of heat to leak out before enough pressure is generated to cause an explosion. But in popcorn with more of hard endosperm, the starch granules are so embedded in tough elastic colloidal material that confines and restricts to steam pressure generated within the granule on heating until it reaches explosive force (Weatherwax, 1922) [10]. Thus when the kernels of popcorn heated the pressure built up within kernel resulted in an explosion and the grain turned inside out. The popped maize is ready to eat products that could be used as snacks, breakfast cereals, adjuncts in brewing. Popping improves the nutritional quality by reducing the ant nutrients, increasing the protein and carbohydrates digestibility and provides dietary fibre in soluble form. Pop based foods are nutritionally adequate and highly acceptable by preschool children.

Flavoured, sugar coated and low fat popped cereals are gaining more importance in the international market. The demand for the popcorn products in the amusement parks, moving theatres, circus and exhibitions is increasing with the increasing urban population. Sowing dates have a pronounced effect on the yield of maize. Maize is generally sown from last week of April to last week of May in lower belts of valley. However, the field may not be vacant at this appropriate time due to delay in harvesting of some rabi crops. Late sowing results in a significant decline in maize production.

In order to achieve higher cob yield, maintenance of stand density is the most important factor. A spatial arrangement of plant governs the shape and size of the leaf area plant^{-1}, which in turn influences efficient interception of radiant energy and proliferation and growth of shoots and their activity. Maximum yield can be expected only when plant population allows individual plants to achieve their maximum inherent potential (Aravinth *et al*., 2011) [1]. Optimum plant population is one of the important factors for higher productivity, by virtue of which there is efficient utilization of underground resources and also harvesting maximum solar radiation which in turn results in better photosynthesis (Monneveux *et al*., 2005) [7]. An optimum plant population for maximum economic yield exists for all crop species and varies with cultivar and environment (Bruns and Abbas, 2005) [2]. Yield increases with increasing plant density up to a maximum for a corn genotype grown under a set of particular environmental and management conditions and declines when plant density is further increased (Gozobenli *et al*., 2004) [3]. Thus, there is need to work out an optimum plant spacing by adjusting inter and intra row spacings in relation to other agronomic factors.

Material Methods

The experiment was conducted at Dryland (Karewa) Agricultural Research Station, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *kharif* 2017. The site is situated between 34.6ºN and 74.5ºE at an altitude of 1580 above Mean sea level. Climatically the experimental site is in mid to high altitude temperate zone characterized by hot summers and very cold winters. The average annual precipitation is 790.4 mm (average of past 30 years) most of which is received from December to April in the form of snow and rains. The soil was silty clay loam with neutral in reaction (pH 6.9) and EC 0.12. The soil was low in Nitrogen (253.7) and Phosphorus (19.4) but medium in Potassium (118.34) and Organic content (0.99). Experiment was laid in split-split plot design assigning three Sowing Dates 19th Standard Metrological week (May 02-May 08) (D_1), 21th Standard Metrological week (May 16-May 22) and 23nd Standard Metrological week (May 30-June 05). Two plant spacings where maintained viz: S_1i.e 60cm X 20cm (83000 plants ha^{-1}) and S_2 i.e. 60cm X 15cm (104166 plants ha-^{1}) along with three nitrogen levels viz: N_1 =90 kg ha^{-1} N_2 =120 kg ha^{-1} and N_3=150 kg ha$^{-1.}$ Nitrogen uptake and content at various growth stages was also examined. The total quantity of phosphorus, potassium and zinc sulphate, were applied as per the recommended dose. Well decomposed FYM @ 10 t ha^{-1}was mixed in soil as per the recommended dose.Urea, DAP, MOP and zinc sulphate were used as source of nitrogen, phosphorus, potassium, and zinc respectively (120 kg N/ha, 60 kg P_2O_5/ha, 30 kg K_2O/ha, 20 kg $ZnSO_4$/ha). Phorate was applied @ 20 kg ha^{-1} one day before sowing for control of cutworms.

Certified seed of maize variety “Shalimar Popcorn 1” was used in the experiment. It has vigorous medium tall plants with a tendency to bear 2 cobs per plant. Cobs are long, tapering towards the end with bright orange flint grains. It has a yield potential of 55 to 60 quintals per hectare. It matures in 155 to 160 days in the valley and 125 to 130 days in the mid elevations. Harvesting was done when the husk of cobs turned brownish yellow. The harvested plants were left on soil surface in respective plots for 3-4 days for sun drying. After sun drying, biomass was recorded with the help of balance. Five plants were randomly selected and tagged from every plot of each replication and then average for every parameter was worked out and recorded after every 15 day interval.

Result and Discussion

Effect on Plant height (cm)

The data on the plant height of maize was recorded at 30 day interval, and observation taken during the investigation has been given in figure1. The progressive increase in the plant height as affected by the different treatments of the study has also been depicted graphically.

A perusal of the data indicated that plant height at 30days after sowing (DAS) in 2016 and 2017 (39.90 and 45.00 cm respectively) for maize sown during 23rdstandard meteorological week (D3) was significantly superior than sowing done during 19th and 21st standard meteorological week (D_1 and D_2 respectively). The lowest plant height of 32.01cm in 2016 and 36.42 cm in 2017 at 30DAS was recorded in maize sown during 19th standard meteorological week (D_1). At 60 DAS, maize sown during 21st standard meteorological week and 23rdstandard meteorological week were at par with each other whereas maize sown during 19th standard meteorological week recorded significantly highest plant height of 170.60 (2016) and 172.44 cm (2017) at 60 DAS, respectively. At 90 DAS plant height maize sown in 19th standard meteorological week was significantly superior whereas plant height in 21st and 23rd standard meteorological week sowing time had slight differences though significant. No significant gain was observed in plant height from 90 DAS to harvest therefore differences between treatments followed similar trends to plant height at 90DAS. The results are in agreement with the observations of Moosavi *et al.* (2012) [6] who reported that there is a significant decline in the plant height with the delay in the planting time of maize, this significant decrease in plant height and stem diameter traits following the delay in sowing can be associated with higher temperatures that the plants at the second and third sowing dates experienced, which limited their growing period and assimilate building because of the early maturity of plants.

With respect to plant spacing, plant height at 30 DAS was at par for both 60cm× 20cm (S_1) and 60cm × 15cm (S_2) in 2016 as well as 2017. At 60 DAS plant height **{**163.58 cm (2016) and 164.88 cm (2017)**}** for S_1 was significantly higher than S_2. At 90 DAS plant height was significantly higher in case of S_1, plant heights viz. 191.13 and 191.95cm (2016 and 2017) were significantly higher than those of S_2. Again plant height at harvest remained almost similar to 90 DAS.

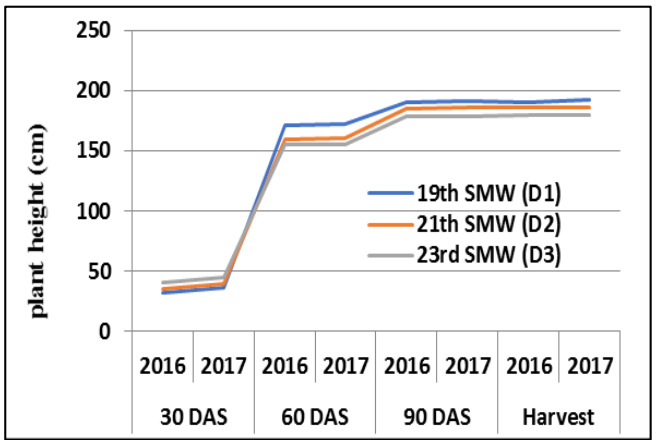

Fig 1: Plant height (cm) of popcorn as influenced by Sowing Dates and Plant Spacing.

Effect on Leaf area index

The data on the leaf area index of maize was recorded at 30 day interval, and observation taken during the investigation has been given in figure 2.Data presented revealed significant variations in leaf area index (LAI) during the growth period of crop. Date of sowing showed a significant variation in leaf area index of maize at all crop growth stages. With delay in sowing there was a significant and consistent increase in leaf area index at 30DAS (days after sowing). At 30DAS significantly lowest leaf area index (0.44 for 2016 and 0.48 for 2017) was observed in sowing done during 19thstandard meteorological week (D_1). At 60DAS, maize crop sown during 19th standard meteorological week (D_1) recorded significantly the highest value for leaf area index (4.82 for 2016 and 4.86 for 2017) over maize sown during 21st standard meteorological week (D_1) and 23rd standard meteorological week (D_3), but LAI decreased at 90DAS as well as at harvest for all three sowing dates. LAI for D_3 was significantly lowest across 30, 60, 90 DAS and harvest stage. Due to spacing LAI (0.44 and 0.48) was significantly higher for 60cm × 15cm (S_2) over S_1 (60cm× 20cm) at 30 and 60DAS (4.86 and 4.90), whereas Leaf area decreased after 60DAS. Moosavi *et al.* (2012) [6] also reported that there is a decline in the leaf area index of maize crop with delay in the sowing time. The same conclusion was also reported by Noferesti *et al.* (2006) [9], delay of sowing leads to reduction in leaf area index of maize because of the shortening of growing cycle.

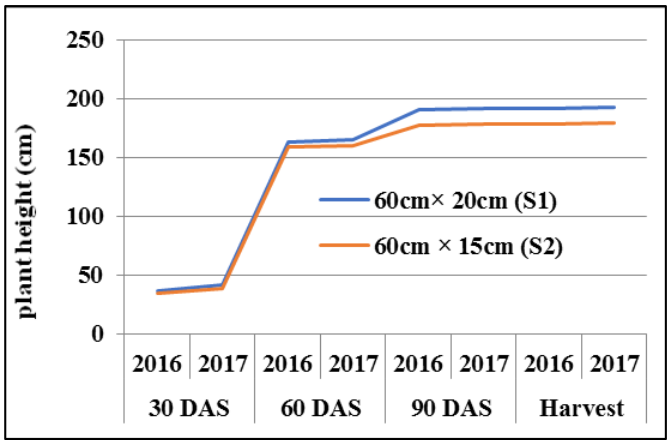

Fig 2: Leaf area index of popcorn as influenced by Sowing Dates, Plant Spacing and Nitrogen Levels

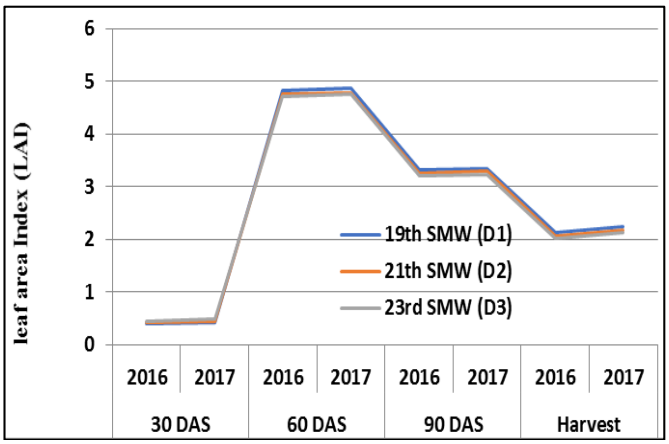

Fig 3: Sowing dates

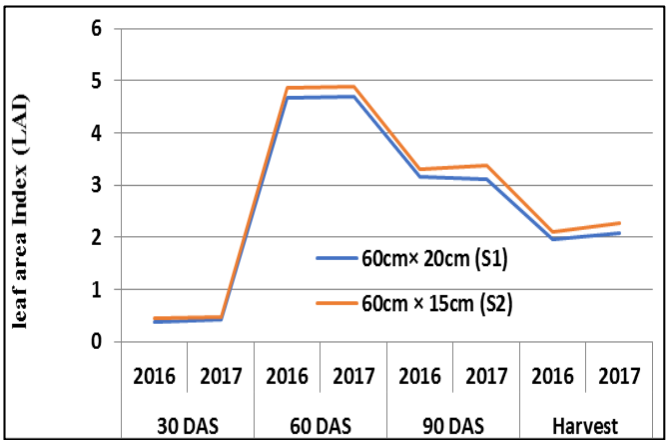

Fig 4: Spacing

Effect on Sped reading

The data was collected at 15 days interval from 15 to 60DAS for years 2016 and 2017. It has been observed that the SPAD reading showed a steady increase from 15 DAS to 60DAS. It was observed from the investigation that the SPAD readings were influenced significantly by sowing time. SPAD reading (37.75 for 2016 and 38.81for 2017) at 15 DAS was significantly superior for popcorn sown on 23rd SMW over 19th (D_1) and 21st (D_2) SMW. From 30 DAS to 60 DAS popcorn sown on 19th SMW recorded highest SPAD reading which was statistically significant over 21st (D_2) and 23rd (D_3) SMW. With respect to spacing at 15 DAS, significantly higher SPAD readings of 37.75 and 38.81(2016 and 2017) were recorded for S_1 (60cm× 20cm). Similar trend was observed at 30, 45 and 60DAS.Non significant Interaction was observed between sowing date and plant spacing with respect to SPAD reading in popcorn.

Effect on yield and yield attributing characters.

Effect on Grain yield (ton ha^{-1})

The experiment was conducted over two years 2016 and 2017. It was observed that a higher grain yield was obtained in 2017 over 2016 for all the three factors under study and respective treatments. The effect of different treatments on grain yield have been presented in Table 1.

A perusal of data indicated that the time of sowing significantly affect the grain yield of popcorn. The sowing time of 19thstandard meteorological week (D_1) harvested

significantly higher grain yield of 3.58 ton ha^{-1} in 2016 and 4.08 ton ha^{-1} in 2017, than sowing time of 21st standard meteorological week (3.41 and 3.59 ton ha^{-1}) and statistically lowest grain yield (3.06 and 3.14 ton ha^{-1}) was harvested during 23rd standard meteorological week sown crop during 2016 and 2017 respectively. The results are in agreement with the results of Jaliya *et al.* (2008), Namakka *et al.* (2008) [8] and Khan *et al.* (2002) [5].

Significantly higher grain yield (3.48 and 3.73 ton ha^{-1}) was obtained in popcorn planted with spacing of S_1 (60cm× 20cm) during 2016 and respectively over S_2 (60cm× 15cm).

Effect on Cobs per plant

The data pertaining to number of cobs per plant as affected by various treatments are presented in table 1 signify that sowing time in Popcorn significantly influenced the number of cobs per plant during years 2016 and 2017. The number of cobs per plant during 2017 was a bit on the higher side than 2016. Popcorn sowing done during 19thstandard meteorological week (D_1) had significantly higher number of cobs per plant (1.48 for 2016 and 1.65 for 2017) then number of cobs per plant in crop sown during 21st (1.41 and 1.57 cobs) and 23rdstandard meteorological week (1.34 and 1.50 cobs). It was observed that spacing also significantly affected number of cobs per plant in popcorn. Popcorn grown with spacing 60cm× 20cm (S_1) had significantly higher number of cobs per plant (1.65 for 2016 and 1.48 for 2017) in comparison with S_1 (1.34 and 1.50).

Effect on Cob length (cm)

From the data given in table 1 a striking variation in the cob length is observed as a result of various treatments. The data taken during 2017 showed lengthier cobs for all treatments as compared to 2016. Cob length varied significantly with sowing time. A gradually significant decline in cob length was observed due to delay in cob length. Sowing done during 19th (D_1) standard meteorological week recorded significantly more cob length than crop sown during 21st standard meteorological week (D_2). Popcorn sown during 23rd SMW (D_3) had significantly lowest cob length than other two treatments. There was a significant influence of spacing on cob length. It was recorded that S_1 (60cm× 20cm) helped in achieving a significantly higher cob length (16.78 and 16.34 cm) over S_2 (60cm × 15cm). Similar findings were also found by Namaka *et al.* (2008) [8] who concluded that the cob length decreased significantly with delay in sowing date. Similar findings were traced by Hassan *et al.* (1998) [4] who found that number of grains per row, and other yield contributing components of maize decreased with delay in sowing date.

Effect on Grains per cob

The number of grains per cob is one of the most important yield contributing character in maize crop. Data presented in table 1 indicated that sowing time affect the number of grains per cob significantly. Data collected during 2017 revealed higher number of grains per cob as compared with 2016. The sowing of maize done during 19th standard meteorological week (D_1) got the highest number of grains per cob (431.61 in 2016 and 472.31 in 2017) over sowing done during 21st (358.91 and 380.37) and 23rd standard meteorological week (301.33 and 312.73). Grains per cob were also significantly affected by plant spacing. Popcorn planted with spacing 60cm× 20cm (S_1) had significantly higher grains per cob, 381.80 in 2016 and 406.85 in 2017. Khan *et al.* (2002) [5] also observed significant decline in the number of grains per cob, 100 grain weight and other yield contributing characters with the delay in sowing time of maize.

Table 1: Yield and yield attributes of popcorn as influenced by Sowing Dates and Plant Spacing

Treatments	Grain yield(t/ha)		Cob/plant		Cob length (cm)		Grains/cob	
	2016	2017	2016	2017	2016	2017	2016	2017
Sowing Dates								
19th SMW (D_1)	3.58	4.08	1.48	1.65	16.77	17.50	431.61	472.31
21th SMW (D_2)	3.41	3.59	1.41	1.57	15.18	15.57	358.91	380.37
23rd SMW (D_3)	3.06	3.14	1.343	1.50	14.67	14.88	301.33	312.73
SE (m)±	0.05	0.04	0.004	0.009	0.23	0.27	4.47	4.94
CD(P≤0.05)	0.15	0.13	0.016	0.036	0.71	0.82	13.42	14.82
Plant Spacing (cm^2)								
60cm× 20cm (S_1)	3.48	3.73	1.48	1.65	16.34	16.78	381.80	406.85
60cm × 15cm (S_2)	3.23	3.48	1.34	1.50	14.74	15.18	346.10	370.09
SE (m)±	0.05	0.06	0.004	0.007	0.33	0.38	3.18	4.25
CD(P≤0.05)	0.17	0.19	0.013	0.020	0.99	1.16	9.54	12.77

Effect on Grains per row

Data presented in table 2 indicated that grains per row were significantly affected by sowing date. Popcorn sown in 19th SMW (D_1) had 32.00 grains per row in 2016 and 33.38 grains per row in 2017 which was significantly higher as compared to crop sown during 21st and 23rd SMW. It was observed that grains per row in the popcorn declined with delay in sowing time. With respect to spacing it was observed that more plant spacing resulted in higher grains per row during both the years 2016 and 2017. Treatment 60cm× 20cm (S_1) produced 30.00 grains per row during 2016 and 30.83 grains per row during 2017 which was significantly higher over S_2 (60cm× 15cm).

Effect on shelling percentage

Variation in shelling percentage as a result of sowing time was highly significant. Popcorn sown during 19th SMW recorded highest shelling percentage of 70.24% in 2016 and 72.74% in 2017. Data from table 2 indicated that with delay in sowing time there was a significant decline in shelling percentage. Crop sown during 23rd SMW had significantly lowest shelling percentage of 60.95% and 62.05% in 2016 and 2017 respectively. A perusal of data indicated that the plant spacing significantly affect the shelling percentage of maize. Popcorn planted with spacing S_1 (60cm× 20cm) achieved significantly higher shelling percentage (67.63% and 69.37%) over S_2 (60cm× 15cm) during both the trial years 2016 and 2017.

Effect on popping percentage

Data pertaining to popping percentage during 2016 and 2017 is presented in table 2. It was observed from table 2 that popcorn sown during 19th Standard Meteorological Week (D_1) achieved significantly higher popping percentage of 81.14 and 83.64% during 2016 and 2017 respectively over crop sown during 21st (D_2) and 23rd (D_3) standard meteorological week. Treatment (D_2) and (D_3) were statistically at par in terms of popping percentage. With respect to plant spacing, treatment S_1 (60cm× 20cm) produced significantly higher popping percentage of 81.11 and 83.62% during 2016 and 2017 respectively against S_2 (60cm× 15cm).

Effect on popping volume

The effect of sowing date, spacing and nitrogen level during the years 2016 and 2017 on popping volume is given in Table 2. From the table 2 it was observed that popcorn sown during 19th, 21st and 23rd standard meteorological week had statistically at par popping volumes. Popping volumes due to plant spacing treatments 60cm× 20cm (S_1) and 60cm × 15cm (S_2) were statistically at par., 1993). It encourages the uptake and utilization of other nutrients including potassium, phosphorous and controls overall growth of plant (Bloom, 2015 and Hemerly, 2016).

In 1923, it was first time reported that B is essential for cell structure of plants (Warington, 1923). The possible roles of B include sugar transport, cell wall synthesis, lignification, cell wall structure integrity, carbohydrate metabolism, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism, and as part of the cell membranes (Parr & Loughman, 1983; Ahmad *et al.*,2009) [5]. Salicylic acid (SA; 2-hydroxybenzoic acid) is an endogenous growth regulator of phenolic nature, which is normally.

Table 2: Yield attributes, popping percentage and popping volume of popcorn as influenced by Sowing Dates and Plant Spacing

Treatments	Grain/row		Shelling percentage		Popping percent		Popping volume	
	2016	2017	2016	2017	2016	2017	2016	2017
Sowing Dates								
19th SMW (D_1)	3.58	4.08	1.48	1.65	16.77	17.50	15.21	15.56
21th SMW (D_2)	3.41	3.59	1.41	1.57	15.18	15.57	14.83	15.19
23rd SMW (D_3)	3.06	3.14	1.343	1.50	14.67	14.88	14.45	14.80
SE (m)±	0.05	0.04	0.004	0.009	0.23	0.27	0.012	0.015
CD(P≤0.05)	0.15	0.13	0.016	0.036	0.71	0.82	0.047	0.059
Plant Spacing (cm^2)								
60cm× 20cm (S_1)	3.48	3.73	1.48	1.65	16.34	16.78	15.25	15.62
60cm × 15cm (S_2)	3.23	3.48	1.34	1.50	14.74	15.18	14.41	14.76
SE (m)±	0.05	0.06	0.004	0.007	0.33	0.38	0.014	0.015
CD(P≤0.05)	0.17	0.19	0.013	0.020	0.99	1.16	0.041	0.042

Conclusion

The results of the investigation showed that amongst different time of sowing, maize sown during 19th standard meteorological week realized significantly higher grain yield of maize. The delay in sowing time results a decline in the yield of maize which could be recovered to some extent when dose and frequency of nitrogen application was increased. The treatment combination of 19th standard meteorological week sowing time 60×20 cm^2 spacing has highest benefit: cost ratio of 4.91. In view of this it was recommended that maize must be sown during 19th standard meteorological week with plant spacing 60×20 cm^2 for obtaining most profitable grain yield of popcorn under rainfed conditions of the valley. Further for delayed sowing yield maximization can be achieved with increase in dose and application frequency of nitrogen (150kg/ha).

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