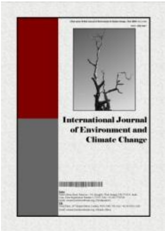

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Effect of Varying Levels of Fertilizers and Date of Sowing on Production and Economic Profitability of *Kharif* Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author SS carried out the experiment. Author SB supervised analyzed and wrote the manuscript. Author GEJ planned the experiment. All authors read and approved the final manuscript.

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ABSTRACT

Maize, being highly nutritious and multi-purpose C_4 crop can be grown throughout the year. Judicious nutrient management and selection of optimum sowing dates play major roles in enhancing productivity and profitability of *kharif* maize to meet the food demand of nation under changing climate scenario. The field experiment was conducted during *khraif* season of 2021 at agricultural farm, Lovely Professional University, Punjab, in split plot design with four fertilizer levels (125, 100, 75, and 50% RDF – recommended dose of fertilizers) in main plots and four sowing dates (15^{th} June, 30^{th} June, 15^{th} July, and 30^{th} July) in sub plots, replicated thrice. Comparatively greater yield attributes as well as grain yield (8.22 t ha^{-1}), stover yield (11.86 t ha^{-1}) and harvest index (40.9%) were observed when maize was grown on 30^{th} June under application of 125% RDF. Production economics indicated that maize grown on 30^{th} June under application of 125% RDF recorded maximum gross return (\$2221 ha^{-1}), net return (\$1446 ha^{-1}), and B:C (2.87). Maize grown on 30^{th} July under application of 50% RDF recorded lowest yield attributes, grain yield (2.70 t ha^{-1}), stover yield (5.31 t ha^{-1}), harvest index (33.7%), gross return (\$739 ha^{-1}), net return (\$19 ha^{-1}) and B:C (1.03).

Keywords: Economics; fertilizer levels; maize; sowing dates; yield.

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1. INTRODUCTION

Maize *(Zea mays* L.), the 'queen of cereals', is grown in all the seasons due to its photo-thermo insensitivity and globally well appreciated for its multi–purpose uses as food, feed, livestock fodder, seed materials and industrial raw materials for production of soup, baby food, flakes, syrup, flour, canned products etc. as well as for its high nutritional values [1].

Among cereals, it ranks 3rd in the world after rice and wheat and grown in 193.96 million ha with a production of 1117.16 million metric tonnes and productivity of 5.76 metric tonnes ha^{-1} [2]. The maize production in India is around 28.77 million metric tonnes from 9.57 million ha area with productivity of 3.01 metric tonnes ha^{-1} [2]. This portrays that there is a need to increase the productivity of maize in India and this can be achieved by various means. Judicious nutrient management can play major role here as maize, being a nutrient exhaustive crop, urges for heavy feeding of nutrients specially nitrogen, phosphorus and potassium [3].

Nitrogen is an essential nutrient responsible for chlorophyll and protein synthesis and thus, helps in enhancing photosynthesis, growth, yield as well as quality of the produce. Similarly, phosphorus is essential for various plant metabolism regarding root and shoot development to ensure better uptakes of nutrients and moisture resulting in high growth and development. Further, potassium is responsible for the movement of nutrients and directly helps in photosynthesis through regulating stomatal opening. Supply of adequate nutrition specially, under poor soil fertility condition, is the key to realize the high yield of heavy feeder crops like maize [4].

Climate change is a major issue that most of crops are facing today. Under the scenario of various biotic and abiotic stresses, cultivation of a crop requires favourable agro-climatic condition for realising the high production. This can be achieved through selection of ideal date for sowing as it can ensure proper germination, plant density, growth, pollination and maturity [5]. Sowing of maize early or beyond the optimum time can lead to poor crop growth and productivity due to climate change impacts. It is, therefore, highly required to examine and compare various dates of sowing for obtaining the most suitable sowing date to achieve maximum production and profitability in maize. Production of a crop does not depend on a single factor and rather, it depends on combination of various factors.

In this context, it is hypothesized that proper standardization of fertilizer levels under optimum date of sowing can create in favourable growth condition which further results in high production and profitability of maize. With this view, the present experiment was planned to examine the effects of fertilizer levels and sowing dates on production and profitability of *kharif* maize.

2. MATERIALS AND METHODS

A field experiment was carried out at agricultural farm (latitude 31^{0}25'N and longitude 75^{0}70'E and 232 m above MSL), School of Agriculture, Lovely Professional University, Phagwara, Punjab, during *khraif* season of 2021 to evaluate the effect of levels of fertilizers and different sowing dates on yield and profitability of maize. The experimental soil was sandy loam in texture having good drainage capacity with neutral pH. The experiment was laid out in split plot design comprising four fertilizer levels (T_1: 125% RDF – recommended dose of fertilizers, T_2: 100% RDF, T_3: 75% RDF, and T_4: 50% RDF) in main plots and four dates of sowing (D_1: 15th June, D_2: 30th June, D_3: 15th July, and D_4: 30th July) in sub plots, replicated thrice. RDF was 120: 60: 40 kg N: P_2O_5: K_2O ha^{-1}. Nitrogen, phosphorus and potassium were supplied from urea, SSP and MOP, respectively. Size of the plot was 4.8 m × 3 m. Maize hybrid 'Laxmi 333' @ 20 kg/ha was sown by flat bed method followed by ridging at a spacing of 60 cm ×25 cm. All the agronomic and plant protection measures were followed as per the standard recommendation for the region.

Observations included various yield attributing and associated characters of maize *viz.* number of cobs plant^{-1}, cob length (cm), cob girth (cm), cob weight (g), number of grains cob^{-1}, 100 grains weight (g). Further, grain yield (t ha^{-1}), stover yield (t ha^{-1}) and harvest index (%) were recorded. For estimation of various yield attributes 10 maize plants were randomly selected from each plot and data on various yield attributes were recorded from each plant and then mean value was computed. Production economics *viz*. cost of cultivation ($ ha^{-1}), gross return ($ ha^{-1}), net return ($ ha^{-1}) and benefit-cost ratio (B:C) were chalked out.

Cost of cultivation ($ ha^{-1}) = Total cost involved in various inputs and package of practice

Gross return ($ ha^{-1}) = Price of product ($ kg^{-1}) × Quantity of the product (kg ha^{-1})

Net return ($ ha^{-1}) = Gross return – net return

B:C = Gross return ($ ha^{-1})/cost of cultivation ($ ha^{-1}).

Data recorded during the experiment were statistically analyzed using 'analysis of variance' method as suggested by Panse and Sukhatme (1985) [6]. Treatment means were compared considering the critical difference (C.D.) value at 5% level of significance. Pearson's correlation coefficients and regression analysis were made to observe relation between yield attributes and their influence on grain yield, respectively.

3. RESULTS AND DISCUSSION

3.1 Yield Attributes of Kharif Maize

Experimental results revealed that various yield attributes of *kharif* maize significantly varied under different levels of fertilizers and date of sowing (Table 1). Among the various fertilizer levels, application of 125% RDF (T_1) resulted in highest number of cobs plant^{-1} (1.25) as well as maximum cob length (17.6 cm) and cob girth (16.2 cm) of *kharif* maize. The highest cob weight (111.6 g), number of grains cob^{-1} (347.7), 100 grains weight (24.88 g) of *kharif* maize were also achieved under application of 125% RDF (T_1). This might be due to improved nutrient uptake with increasing supply in fertilizer quantity and consequently, high leaf expansion, chlorophyll contents, photosynthetic efficiency and partitioning of photo-assimilates to development of reproductive organs [7].

With the decrease of fertilizer levels in *kharif* maize, the above yield attributes declined and the lowest number of cobs plant^{-1} (1.00), cob length (11.2 cm), cob girth (13.8 cm), cob weight (72.9 g), number of grains cob^{-1} (218.1), and 100 grains weight (21.95 g) were recorded under application of 50% RDF (T_4). The result was in line with the findings of Gul et al. [8]. Considering the impact of date of sowing, it was observed that number of cobs plant^{-1} (1.13), cob length (16.0 cm), cob girth (16.0 cm), cob weight (103.4 g), number of grains cob^{-1} (316.6), and 100 grains weight (24.18 g) were highest when maize was sown on 30th June (D_2), followed by sowing on 15th July (D_3). Maize sown on 30th July (D_4) recorded lowest number of cobs plant^{-1} (1.05), cob length (13.5 cm), cob girth (13.3 cm), cob weight (88.0 g), number of grains cob^{-1} (270.1) and 100 grains weight (22.67 g). Delayed sowing of maize in 15th July and 30th July might result in low photosynthesis due to overcast of sky during monsoon season, which reduced radiation interception by the maize plants.

Similar finding was observed by Rani et al. [9]. Sowing on 15th June resulted in poor development of reproductive organs perhaps due to high edapho-climatic temperature and lack of soil moisture at the early stage of crop growth before start of monsoon. Interaction between fertilizer levels and sowing dates exhibited significant variations in different yield attributes of *kharif* maize except number of cobs plant^{-1} (Table 1). Maize sown on 30th July under application of 125% RDF (T_1D_2) recorded highest number of cobs plant^{-1} (1.31), cob length (18.5 cm), cob girth (17.1 cm), cob weight (122.2 g), number of grains/cob (374.8) and 100 grains weight (25.95 g), which was followed by maize sown on 15th July under 125% RDF (T_1D_3). Lowest yield attributes were recorded by maize sown on 30th July under 50% RDF (T_4D_4). It might be due to nutrient starved situation resulting from high leaching loss of nutrients along with less supply of nutrients under active monsoon period.

3.2 Seed Yield, Stover Yield and Harvest Index of Kharif Maize

Seed yield, stover yield and harvest index of *kharif* maize were significantly influenced by fertilizer levels and date of sowing individually and in combination (Table 2). Among the fertilizer levels, the highest seed yield (7.00 t ha^{-1}), stover yield (10.54 t ha^{-1}) and harvest index (39.8%) of *kharif* maize were observed under application of 125% RDF (T_1), which was next followed by 100% RDF (T_2). Application of 50% RDF (T_4) recorded lowest seed yield (3.10 t ha^{-1}), stover yield (5.72 t ha^{-1}) and harvest index (35.1 %) of *kharif* maize.

Increase in yield attributes due to application of nutrients perhaps directly reflected to grain yield of *kharif* maize. Positive influence of high supply of nutrients on photosynthesis and translocation of nutrients from source to sink (grain) might favour grain yield as well as harvest index. Further, high stover yield under increased levels of fertilizer was probably due to high photosynthesis and dry matter accumulation of the crop. Photosynthesis efficiency was probably

Table 1. Effect of fertilizer levels and sowing dates on yield attributes of *kharif* maize

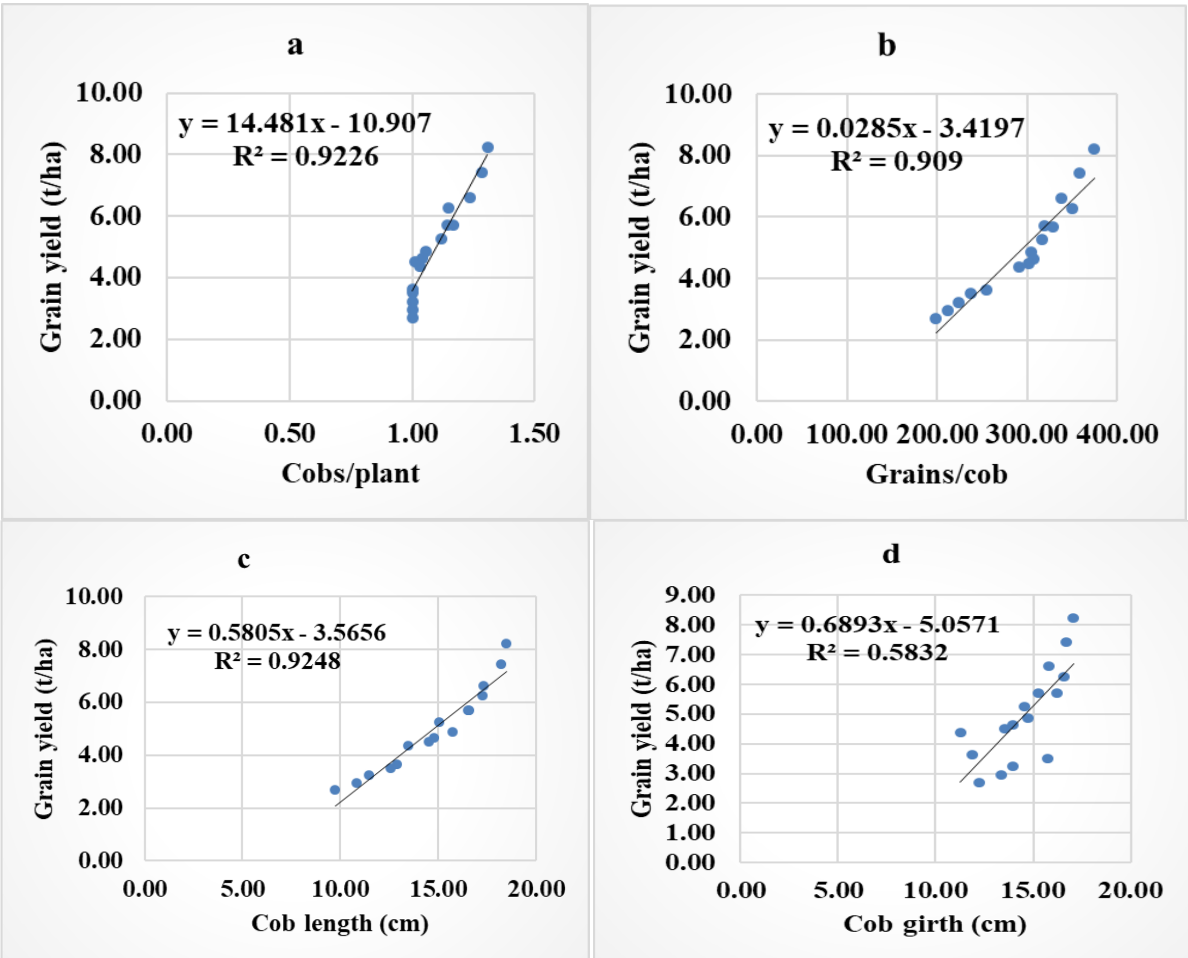
Treatments	Number of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	Cob weight (g)	Number of grains cob^{-1}	100 grains weight (g)
Fertilizer levels						
T_1	1.25	17.6	16.2	111.6	347.7	24.88
T_2	1.11	15.9	15.3	103.1	325.5	23.98
T_3	1.03	14.1	12.8	95.7	288.2	22.76
T_4	1.00	11.2	13.8	72.9	218.1	21.95
S. Em (±)	0.011	0.07	0.12	1.5	6.2	0.04
C. D. (P= 0.05)	0.04	0.2	0.4	5.1	21.9	0.13
Dates of sowing						
D_1	1.10	14.2	13.7	93.7	289.6	23.14
D_2	1.13	16.0	16.0	103.4	316.6	24.18
D_3	1.11	15.2	15.1	98.2	303.2	23.57
D_4	1.05	13.5	13.3	88.0	270.1	22.67
S. Em (±)	0.016	0.08	0.10	0.4	1.6	0.04
C. D. (P= 0.05)	0.05	0.2	0.3	1.1	4.8	0.12
Interaction						
T_1D_1	1.24	17.3	15.8	108.3	338.6	24.61
T_1D_2	1.31	18.5	17.1	122.2	374.8	25.95
T_1D_3	1.28	18.2	16.7	114.7	358.1	25.04
T_1D_4	1.17	16.6	15.3	101.4	319.3	23.91
T_2D_1	1.12	15.1	14.6	100.2	316.5	23.77
T_2D_2	1.15	17.3	16.6	111.2	349.7	24.65
T_2D_3	1.14	16.5	16.2	104.2	328.4	24.11
T_2D_4	1.04	14.8	14.0	96.9	307.3	23.39
T_3D_1	1.03	13.5	11.3	95.8	291.4	22.56
T_3D_2	1.06	15.7	14.7	101.2	304.2	23.39
T_3D_3	1.01	14.5	13.5	98.9	302.0	22.81
T_3D_4	1.00	12.9	11.9	86.8	255.2	22.27
T_4D_1	1.00	10.8	13.3	70.8	211.9	21.61
T_4D_2	1.00	12.6	15.8	79.1	237.7	22.75
T_4D_3	1.00	11.5	14.0	75.0	224.2	22.31
T_4D_4	1.00	9.7	12.2	66.9	198.6	21.11

Treatments	Number of cobs plant^{-1}		Cob length (cm)		Cob girth (cm)		Cob weight (g)		Number of grains cob^{-1}		100 grains weight (g)	
	T×D	**D×T**	**T×D**	**D×T**	**T×D**	**D×T**	**T×D**	**D×T**	**T×D**	**D×T**	**T×D**	**D×T**
S. Em (±)	0.023	0.031	0.14	0.15	0.24	0.21	2.9	1.6	12.4	6.8	0.07	0.08
C. D. (P= 0.05)	NS	NS	0.5	0.5	0.6	0.7	2.6	5.5	11.2	23.3	0.25	0.25

increased due to nitrogen application as it was the constituent of chlorophyll. Further, phosphorus might play important role in root development resulting in high nutrient uptakes. Potassium as an activator of various enzymes, perhaps not only facilitated CO_2 entry through stomata but also helped in translocation of assimilates from source to sink.

Similar type of findings was earlier documented by Chitransha et al. [10]. Among various dates of sowing, maize sown on 30th June recorded highest seed yield (5.71 t ha^{-1}), stover yield (9.09 t ha^{-1}) and harvest index (38.2%), which was next followed by maize sown on 15th July. Maize sown on 30th July exhibited lowest seed yield (4.17 t ha^{-1}), stover yield (7.42 t ha^{-1}) and harvest index (35.6%). It might be due to loss of nutrients through leaching under high rainfall as well as poor radiation utilization under cloudy condition. Derby et al. [11] opined that photosynthesis, transfer of assimilates to sink (grains) depended on optimum utilization of sunlight and assimilation of CO_2.

Interaction between fertilizer levels and sowing dates expressed that maize sown under application of 125% RDF on 30th June (T_1D_2) recorded the highest seed yield (8.22 t ha^{-1}), stover yield (11.86 t ha^{-1}) and harvest index (40.9%), which was next followed by maize sown under 100% RDF on 30th June (T_2D_2). Maize sown under 50% RDF on 30th July (T_4D_4) showed lowest seed yield (2.70 t ha^{-1}), stover yield (5.31 t ha^{-1}) and harvest index (33.7%). Along with poor radiation utilization and nutrient loss through leaching, delayed sowing faced terminal cool period during later stage which might shorten the period for development of reproductive organs, resulting in low yield and harvest index. Limited application of nutrients might make nutrient scare situation under high rainfall condition, which directly impacted on poor yield and harvest index of maize.



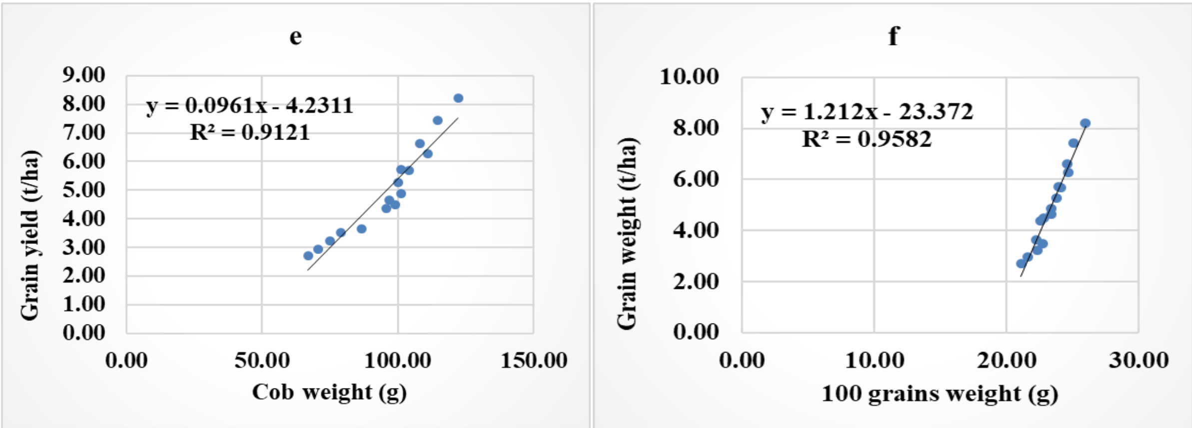


Fig. 1. Relationship between grain yield and (a) cobs plant^{-1}, (b) grains cob^{-1}, (c) cob length, (d) cob girth, (e) cob weight, (f) 100 grains weight

Table 2. Effect of fertilizer levels and sowing dates on grain yield, stover yield and harvest index of *kharif* maize

Treatments	Grain yield (t ha^{-1})		Stover yield (t ha^{-1})		Harvest index (%)	
Fertilizer levels						
T_1	7.00		10.54		39.8	
T_2	5.47		9.07		37.5	
T_3	4.34		7.85		35.6	
T_4	3.10		5.72		35.1	
S. Em (±)	0.05		0.06		0.15	
C. D. (P= 0.05)	0.17		0.21		0.5	
Dates of sowing						
D_1	4.80		8.11		36.8	
D_2	5.71		9.09		38.2	
D_3	5.21		8.55		37.4	
D_4	4.17		7.42		35.6	
S. Em (±)	0.05		0.07		0.06	
C. D. (P= 0.05)	0.14		0.20		0.2	
Interaction						
T_1D_1	6.62		10.13		39.5	
T_1D_2	8.22		11.86		40.9	
T_1D_3	7.43		11.03		40.2	
T_1D_4	5.72		9.14		38.5	
T_2D_1	5.26		8.86		37.2	
T_2D_2	6.27		9.93		38.7	
T_2D_3	5.70		9.35		37.9	
T_2D_4	4.65		8.13		36.4	
T_3D_1	4.37		7.89		35.7	
T_3D_2	4.87		8.44		36.6	
T_3D_3	4.50		7.98		36.1	
T_3D_4	3.64		7.09		33.9	
T_4D_1	2.95		5.57		34.6	
T_4D_2	3.51		6.12		36.4	
T_4D_3	3.23		5.86		35.6	
T_4D_4	2.70		5.31		33.7	
	T×D	**D×T**	**T×D**	**D×T**	**T×D**	**D×T**
S. Em (±)	0.10	0.10	0.12	0.13	0.29	0.18
C. D. (P= 0.05)	0.30	0.30	0.42	0.41	0.4	0.6

Table 3. Correlation matrix of various yield attributes of *kharif* maize under varying fertilizer levels and sowing dates

	Cobs plant^{-1}	Grains cob^{-1}	Cob length	Cob weight	100 grains weight	Cob girth
Cobs plant^{-1}	1					
Grains cob^{-1}	0.998**	1				
Cob length	0.997**	1.000**	1			
Cob weight	0.990**	0.989**	0.991**	1		
100 grains weight	0.989**	0.991**	0.992**	0.998**	1	
Cob girth	0.989**	0.991**	0.993**	0.998**	1.000**	1

***Highly significant*

Table 4. Effect of fertilizer levels and sowing dates on production economics of *kharif* maize

Treatments	Cost of cultivation (\$ ha^{-1})	Gross return* (\$ ha^{-1})	Net return (\$ ha^{-1})	B:C
Fertilizer levels				
T_1	775	1893	1119	2.44
T_2	757	1486	729	1.97
T_3	738	1185	446	1.60
T_4	720	845	125	1.18
Dates of sowing				
D_1	748	1305	557	1.73
D_2	748	1550	803	2.06
D_3	748	1416	668	1.88
D_4	748	1138	390	1.51
Interaction				
T_1D_1	775	1792	1018	2.31
T_1D_2	775	2221	1446	2.87
T_1D_3	775	2009	1235	2.59
T_1D_4	775	1551	776	2.00
T_2D_1	757	1430	673	1.89
T_2D_2	757	1700	943	2.25
T_2D_3	757	1547	791	2.05
T_2D_4	757	1266	509	1.67
T_3D_1	738	1191	453	1.61
T_3D_2	738	1325	587	1.79
T_3D_3	738	1226	487	1.66
T_3D_4	738	996	257	1.35
T_4D_1	720	806	85	1.12
T_4D_2	720	955	235	1.33
T_4D_3	720	881	160	1.22
T_4D_4	720	739	19	1.03

**Price of maize grain and stover: \$ 0.26 kg^{-1} and \$ 6.60 t^{-1}, respectively; 1\$ = ₹75.77*

3.3 Correlation between Different Yield Attributes and Their Relationships with Grain Yield

Pearson's correlation coefficients indicated that there existed positive and very strong correlations between different yield attributes (r value ranging from 0.989 to 1.0), specially, among cob length and grains cob^{-1} (r =1.0) and cob girth and 100 grains weight (r =1.0) (Table 3). This indicated that under different fertilizer levels and sowing dates, change in one yield attributes caused positive change in other attributes. Further, linear regression relationships between yield attributes with grain yield were observed under different fertilizer levels and sowing dates (Fig. 1). As per the coefficient of determination value (R^2) existed between grain yield and (a) cobs plant^{-1} (R^2 = 0.9226), (b) grains cob^{-1} (R^2 = 0.9090), (c) cob length (R^2 = 0.9248), (d) cob girth (R^2 = 0.5832), (e) cob weight (R^2 = 0.9121), (f) 100 grains weight (R^2 = 0.9582), the linear regression models were able to explain 92.26, 90.90, 92.48, 58.32, 91.21, and 95.82% variations between grain yield and (a) cobs plant^{-1}, (b) grains cob^{-1}, (c) cob length, (d) cob girth, (e) cob weight, (f) 100 grains weight, respectively. It also indicated that except cob girth, changes in yield attributes (specially, 100 grains weight) of X-axis caused significant changes in grain yield of Y-axis.

3.4 Economics

Production economics showed that cost of cultivation of *kharif* maize did not change with sowing dates (\$748 ha^{-1}) (Table 4). However, it was increased with increase of fertilizer levels, where costs of cultivation were maximum (\$775 ha^{-1}) and minimum (\$720 ha^{-1}) under application of 125% RDF (T_1) and 50% RDF, respectively. Variable cost of cultivation was possibly due to differential use of fertilizer quantity. Gross return, net return and B:C also followed the identical trend, in which 125% RDF recorded highest gross return (\$1893 ha^{-1}), net return (\$1119 ha^{-1}) and B:C (2.44). High production of yield due to beneficial impact of increased quantity and availability of nutrients might fetched highest gross return, net return and indicated most economic profitability.

The result was in conformity with the finding of Rehman et al. [12]. Among sowing dates, highest gross return (\$1550 ha^{-1}), net return (\$803 ha^{-1}) and B:C (2.06) were seen from maize grown on 30th June (D_2), followed by 15th July (D_3), 15th June (D_1) and 30th July (D_4). It was due to greater utilization of onset of rainy season for seed germination and plant stand establishment as well as adequate capture of solar radiation, which directly helped in photosynthesis and development of reproductive organs and thereby, positively influenced production economics. The result corroborated the finding of Prasad et al. [13]. Considering the interaction effect, maize grown on 30th June under application 125% RDF (T_1D_2) recorded highest gross return (\$2221 ha^{-1}), net return (\$1446 ha^{-1}) and B:C (2.87), while lowest gross return (\$739 ha^{-1}), net return (\$19 ha^{-1}) and B:C (1.03) were observed from maize grown on 30th July under application of 50% RDF (T_4D_4). Similar finding was observed by Rani et al. [9].

4. CONCLUSION

From the study, it was found that both nutrient dose and sowing dates were key factors in influencing performance of *kharif* maize in Punjab condition. Overall, study concluded that maize can be grown preferably on 30th June under 125% recommended dose of fertilizers for achieving high yield and profitability during *kharif* season in Punjab, India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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