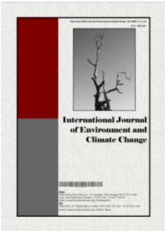

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Effect of Macronutrient Levels, Micronutrient Mixture and Humic Acid on Yield and Economics of *Kharif* Maize

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Authors' contributions

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

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ABSTRACT

Background: Cultivation of Maize, a highly productive and profitable crop, requires standardization of macronutrients, micronutrients and organic nutrition.
Objective: Research was planned with the objective to enhance the yield and profit of *kharif* maize by agronomic fortification through macronutrients, micronutrient mixture and humic acid.
Method: The field experiment was conducted at agricultural farm, Lovely Professional University, Punjab in randomized block design with 10 nutrient management treatments ((T_0: control (100% RDF), T_1: T_0 +soil application of micronutrient mixture (MM) @10kg/ha, T_2: T_0+ foliar application of MM @1%, T_3: T_0+ seed priming with MM @1%, T_4: 75% RDF+ soil application of MM@10kg/ha, T_5: 75% RDF+ foliar application of MM@1%, T_6: 75% RDF+ seed priming with MM @1%, T_7: T_4+ humic acid @1%, T_8: T_5+humic acid @1% at 30 days after sowing (DAS), T_9: T_6+ foliar application of humic acid@1% at 30 DAS).
Results: Among various macronutrients, micronutrient mixture and humic acid combinations, T_8 treatment recorded relatively higher yield attributes like cobs/plant (1.18), cob length (18.8 cm), cob girth (17.6 cm), cob weight with (143.80 g) or without (132.56 g) husk, grains row/cob (14.1), grains/row (26.8), 100 grains weight (27.1 g), grain yield (7.83 t/ha), stover yield (10.13 t/ha) and harvest index (43.61%), which was remained statistically similar by T_7 treatment. Production economics further, revealed that T_8 treatment was the most profitable (net return: ₹ 1,02,253/ha and B:C: 2.78) and therefore, can be recommended for *kharif* maize cultivation in Punjab.

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Keywords: Economics; humic acid; macronutrients; maize; micronutrient mixture; yield.

1. INTRODUCTION

Maize, having photo-thermal insensitive character, high adoption potential, nutritional benefits and production prospect, can be grown worldwide throughout the year for various purposes like staple food, livestock feed, industrial raw materials to produce corn oil, sugar, flour, syrup, alcohol, baby foods, canned foods etc. [1]. In India, it is cultivated on area of 9.57 million ha with a production of 28.77 million metric tonnes and productivity of 3.01 metric tonnes/ha [2]. The productivity of maize is comparatively low than world average (5.76 metric tonnes/ha) and it can be addressed by incorporating various modern agricultural interventions. Ideal nutrient management is one major driver of successful maize production.

Being a highly exhaustive crop, it requires high quantity of primary nutrient (N, P, K) fertilizers. Adequate application of nitrogen, phosphorus and potassium can enhance maize growth and thereby, production through their beneficial roles in photosynthesis, root development for uptake of nutrients and water and capturing CO_2 and sunlight for photosynthesis, respectively. Along with these macronutrients, high maize productivity can be realized under additional availability of various micronutrients. As Indian soils are deficient in micronutrients (Zn, Fe, Cu, Mn, B), plant growth and yield can be enhanced by judicious and balanced application of small quantity of micronutrients externally in the form of micronutrient mixture through soil application or foliar spray. Anitha and kadalli (2019) [3] showed that soil and foliar application of micronutrient mixture resulted in high grain and stover yield of maize. However, considering the environmental footprints made by inorganic fertilizers, their use should be curtailed down by substituting a certain part with organic nutrient source and such integrated nutrient management can benefit crop to ensure high productivity and profitability under changing climate scenario. Humic acid is one popular organic nutrient source which can ensure high maize growth and yield through enhancing macro and micro nutrient uptakes [4]. Apart from the different types and sources of nutrients, method of their application also play a key role in enhancing the crop productivity and profitability to high extent. In this context, other than soil and foliar nutrient applications, nutri-seed priming i.e. pre-sowing controlled hydration technique through soaking seeds in macro and micronutrients rich solution to encourage some biochemical and physiological changes in seeds for starting various metabolic activities without actually permitting the seeds to germinate, is showing prospect [5]. In recent days, seed priming with micronutrient mixture is practiced to ensure yield and quality of crop [6]. To achieve successful and profitable production of maize, it is, therefore, imperative to evaluate and standardise the suitable nutrient type, source, method and dose for the crop. Considering all the facts, the present investigation was panned.

2. MATERIALS AND METHODS

The field experiment was carried out in agricultural farm (latitude 31º25'N and longitude 75º70'E and 232 m above MSL), School of Agriculture, Lovely Professional University, Phagwara, Punjab, during *kharif* season of 2021 to observe the response of *kharif* maize to macronutrient levels, micronutrient mixture and humic acid under application through soil, foliar and seed priming. The experiment was laid out in randomized block design (RBD) with 3 replications consisting of 10 treatments (T_0: control (recommended dose of fertilizer i.e. RDF), T_1: 100% RDF +soil application of micronutrient mixture (MM) @10kg/ha, T_2: 100% RDF+ foliar application of MM @1%, T_3: 100% RDF+ seed priming with MM @1%, T_4: 75% RDF+ soil application of MM@10kg/ha, T_5: 75%RDF+foliar application of MM@1%, T_6: 75% RDF+ seed priming with MM @1%, T_7: 75% RDF+ soil application of MM @10kg/ha+ humic acid @1%, T_8: 75% RDF+ foliar application of MM@1%+humic acid @1% at 30 days after sowing (DAS), T_9: 75%RDF+seed priming with MM@1%+ foliar application of humic acid@1% at 30DAS). Micronutrient mixture consists of 12.5g $FeSO_4$, 25g $MnSO_4$, 100g $ZnSO_4$, 350g Borax and 4.5g $CuSO_4$. Macronutrients viz. nitrogen, phosphorus and potassium were supplied from urea, DAP and MOP, respectively. 100% RDF comprised 120 kg nitrogen, 60 kg phosphorus and 40 kg potassium on a hectare basis. Hybrid maize '3033' @ 20 kg/ha was sown on July 2nd, 2021 at a spacing of 60 cm × 25 cm in individual plot of 4.8 m × 4 m size. Standard package of practices and pest protection measures recommended for the region were followed during crop cultivation period.

Observation covered number of cobs/plant, cob length and girth, cob weight with and without husk, number of grains row/cob, number of grains/row, 100 grains weight, grain yield, stover yield and harvest index. Harvest index was calculated using the following formula:

- Harvest index (%) = [Grain yield/ (grain yield + stover yield)] × 100
  Finally, production economics such as cost of cultivation (₹ /ha), gross return (₹ /ha), net return (₹ /ha) and Benefit-cost ratio (B:C) were chalked out as per the following formulas:
- Cost of cultivation (₹ /ha) = Total cost involved in various inputs and package of practice
- Gross return (₹ /ha) = Price of product (₹ /kg) × Quantity of the product (kg/ha)
- Net return (₹ /ha) = Gross return (₹ /ha) – cost of cultivation (₹ /ha)
- B:C = Gross return (₹ /ha)/cost of cultivation (₹ /ha).

Data collected from field experiment were statistically analyzed using 'analysis of variance' technique [7] and treatment means were compared according to critical difference (C.D.) values at 5% significance level. In order to find out relation between yield attributes and their influence on grain yield, Pearson's correlation coefficients and regression analysis were carried out, respectively.

3. RESULTS AND DISCUSSION

3.1 Yield Attributes of Maize

Results present in Table 1 indicated significant variations of yield attributing characters of *kharif* maize under varying macronutrient levels, micronutrient mixture and humic acid application except number of grains row/cob. Maximum number of cobs/plant (1.18), cob length (18.8 cm) and girth (17.6 cm), cob weight with husk (143.80 g) and without husk (132.56 g) were recorded from application of 75% RDF + foliar application of MM@1% + humic acid @1% at 30 days after sowing (DAS) (T_8), followed by 75% RDF + soil application of MM@10kg/ha + humic acid @1% at 30 DAS (T_7) (cobs/plant:1.14, cob length: 17.8 cm and girth: 16.7 cm, cob weight with husk: 138.64 g and without husk: 126.31 g) and both these remained statistically indifferent to each other. Application of humic acid might ensure the positive impact on plant nutrient uptakes by favouring water retention and development of roots as well as photosynthesis and thereby, further translocation of dry matter to reproductive part of maize [4]. Lowest number of cobs/plant (1.00), cob length (14.3 cm) and girth (14.1 cm), cob length (14.3 cm) and girth (14.1 cm) were observed from application of 75% RDF + seed priming with MM@ 1% before sowing (T_6). It indicated that as compared to soil and foliar application, seed priming showed least effect on crop development and formation of reproductive organs. Number of grains row/cob did not vary among the various nutrient management levels and it ranged from 12.6 to 14.1 as observed from application of 75% RDF + seed priming with MM@1% before sowing (T_6) and application of 75% RDF + foliar application of MM@1% + humic acid @1% at 30 DAS (T_8), respectively. Application of 75% RDF + foliar application of MM@1% + humic acid @1% at 30 DAS (T_8) also ensured maximum number of grains/row (26.8) and 100 grains weight (27.1 g) of *kharif* maize, which was closely followed and shown statistical similarity by 75% RDF + soil application of MM@10kg/ha + humic acid@1% at 30DAS (T_7) (grains/row: 25.7 and 100 grains weight: 26.9 g). Application of 75% RDF + seed priming with MM@1% before sowing (T_6) recorded lowest number of grains/row (21.1) and 100 grains weight (23.0 g) of *kharif* maize. Among soil and foliar applications, foliar application showed greater performance due to plant's high efficiency in absorbing the liquid through diffusion as compared to soil application in which certain part of nutrients becomes unavailable through interaction with soil properties [8]. Losses of nutrients were also restricted under foliar application leading to rapid utilization of nutrients. Positive influence of micronutrients Zn, B, Fe, Mn and Cu in physiological and biochemical metabolism such as photosynthesis, pollination and grain formation etc. [9] probably reflected on greater yield attributes of maize as compared to sole RDF. Efficacy of foliar application micronutrient mixtures on development of various yield attributes was earlier also confirmed by Parasuraman [10].

3.2 Grain yield, stover yield and harvest index of maize

There existed significant variations among the different nutrient management options for grain yield, stover yield and harvest index of *kharif* maize (Table 2). Application of 75% RDF + foliar application of MM@1% + humic acid @1% at 30 DAS (T_8) recorded maximum grain yield (7.83 t/ha), stover yield (10.13 t/ha) and harvest index (43.61%) of *kharif* maize. However, grain yield

(7.15 t/ha), stover yield (9.55 t/ha) and harvest index (42.73%) achieved under application of 75% RDF + soil application of MM@10kg/ha + humic acid@1% at 30DAS (T_7) remained statistically at par with those achieved under T_8 treatment. The sequence of nutrient management options for recording grain yield, stover yield and harvest index was T_8>T_7>T_2>T_1>T_9>T_5>T_4>T_3>T_0>T_6. Application of 75% RDF + seed priming with MM@1% before sowing (T_6) recorded lowest grain yield (4.42 t/ha), stover yield (6.82 t/ha) and harvest index (39.30%) of *kharif* maize. High grain yield and harvest index were the results of improvement in yield attributes that contributed to economic part (grain) of maize. Both soil application of macronutrients along with foliar application of micronutrient mixtures and organic source of nutrient viz. humic acid might create favourable environment for the maize to produce dry matter and translocate these from source to sink (grain). Foliar application of micronutrients possibly provided greater and quicker translocation of micronutrients inside the plant, which resulted in high yield attributes and in turn, impacted positively on yield of maize. Additionally, application of humic acid also perhaps resulted in improvement of nutrient uptakes and thereby, facilitated photosynthesis and dry matter accumulation. It positively impacted not only on grain yield but also on stover yield, confirming the overall growth of maize. The present result was in line with the finding of Adarsha et al. [11].

3.3 Correlation between Various Yield Attributes and their Relationships with Grain Yield

Correlation coefficient values (Table 3) indicated that there existed positive correlation between various yield attributes of *kharif* maize under various nutrient management options. Positive and strongest existed between cob weight with husk and cob girth (r = 0.992) and cob weight with husk and without husk (r = 0.992), which were followed by correlation between cob weight without husk and cob girth (r = 0.988) and grain rows/cob and cob weight without husk (r = 0.981), grains/row and 100 grains weight (r = 0.974), grain rows/cob and cob weight with husk (r =0.974). Relatively weak but positive correlation existed between grains/row and cob length (r= 0.749), grains/row and cobs/plant (r = 0.764), 100 grains weight and cob length (r = 0.775), 100 grains weight and cobs/plant (r = 0.785). There existed liner regression relationships between various yield attributes with grain yield of *kharif* maize and change in variable of X- axis caused significant change in variable of Y-axis (Fig 1). As per the coefficient of determination (R^2), closest relationship was found between cob weight with husk and grain yield (R^2 = 0.9776), while, relatively weakest relationship was observed between grain yield and grains/row (R^2 = 0.8573). Overall, the linear regression models were able to explain 91.43%, 95.96%, 95.90%, 97.76%, 96.79%, 95.11%, 85.73% and 95.44% variations between grain yield and (a) cobs/plant, (b) cob length, (c) cob girth, (d) cob weight with husk, (e) cob weight without husk, (f) grains row/cob, (g) grains/row, (h) 100 grains weight, respectively.

3.4 Production Economics

Considering the production economics (Table 4), among various treatments, maximum cost of cultivation (₹57,455/ha) was incurred under application of 75% RDF + foliar application of MM@1% + humic acid @1% at 30 DAS (T_8), followed by application of 75% RDF + soil application of MM@10kg/ha + humic acid@1% at 30DAS (T_7) (₹57,431/ha), while lowest cost of cultivation was noticed under application of 75% RDF + seed priming with MM@1% before sowing (T_6) (₹54,588/ha). It was probably due to cost involved in humic acid and micronutrient mixture along with 75% RDF. However, application of 75% RDF + foliar application of MM@1% + humic acid @1% at 30 DAS (T_8) also ensured highest gross return (₹1,59,708/ha), net return (₹1,02,253/ha) and B:C (2.78) and it was next followed by application of 75% RDF + soil application of MM@10kg/ha + humic acid@1% at 30DAS (T_7) (gross return: ₹1,45,988/ha, net return: 88,556/ha, B:C: 2.54). The maximum gross return and economic profitability was due to greater production of maize under positive influence of T_8 due to presence of humic acid and micronutrient mixture along with macronutrients. Almost similar type of observation was earlier documented by Anitha and kadalli (2019) [3]. Application of 75% RDF + seed priming with MM@1% before sowing (T_6) recorded lowest gross return (₹90,705/ha), net return (₹36,117/ha) and B:C (1.66) in *kharif* maize. It was due to least effect of seed priming on development of maize reproductive organs.

Table 1. Effect of macronutrient levels, micronutrient mixture and humic acid on yield attributes of *kharif* maize

Treatments	Number of cobs/plant	Cob length (cm)	Cob girth (cm)	Cob weight with husk (g)	Cob weight without husk (g)	Number of grains row/cob	Number of grains/row	100 grains weight (g)
T_0	1.03	14.9	14.6	117.23	107.53	13.2	24.6	23.9
T_1	1.05	16.6	15.9	125.45	114.05	13.5	24.7	25.1
T_2	1.07	17.2	16.1	133.61	123.45	13.7	25.7	26.5
T_3	1.02	15.1	14.8	114.96	103.83	13.0	23.3	24.3
T_4	1.03	15.3	15.0	118.02	105.76	13.2	23.4	24.4
T_5	1.04	15.7	15.4	118.66	108.46	13.3	24.0	24.6
T_6	1.00	14.3	14.1	107.35	96.15	12.6	21.1	23.0
T_7	1.14	17.8	16.7	138.64	126.31	13.9	25.7	26.9
T_8	1.18	18.8	17.6	143.80	132.56	14.1	26.8	27.1
T_9	1.04	16.5	15.8	123.21	110.98	13.4	24.1	25.0
S. Em. (±)	0.02	0.54	0.41	5.02	4.65	0.78	0.69	0.73
C. D. (P= 0.05)	0.07	1.6	1.2	15.02	13.92	NS	2.1	2.19

T_0: Control (RDF); T_1: RDF + soil application of micronutrient mixture@10kg/ha at 30DAS; T_2: RDF + foliar application of micronutrient mixture@1% at 30DAS; T_3: RDF + seed priming with micronutrient mixture@1% before sowing; T_4: 75% RDF + soil application of micronutrient mixture@10kg/ha at 30DAS; T_5: 75% RDF + foliar application of micronutrient mixture@1% at 30DAS; T_6: 75% RDF + seed priming with micronutrient mixture@1% before sowing; T_7: 75% RDF + soil application of micronutrient mixture@10kg/ha + humic acid@1% at 30DAS; T_8: 75% RDF + foliar application of micronutrient mixture@1% + humic acid@1% at 30DAS; T_9: 75% RDF + seed priming@1% before sowing + humic acid@1% at 30DAS; Micronutrient mixture: 12.5g $FeSO_4$, 25g $MnSO_4$, 100g $ZnSO_4$, 350g Borax and 4.5g $CuSO_4$)

Table 2. Effect of macronutrient levels, micronutrient mixture and humic acid on seed yield, stover yield and harvest index of *kharif* maize

Treatments	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
T_0	5.32	8.12	39.54
T_1	6.05	8.65	41.10
T_2	6.60	9.16	41.72
T_3	5.52	8.42	39.59
T_4	5.46	8.21	39.92
T_5	5.57	8.27	40.24
T_6	4.42	6.82	39.30
T_7	7.15	9.55	42.73
T_8	7.83	10.13	43.61
T_9	5.92	8.52	40.97
S. Em. (±)	0.37	0.38	0.44
C. D. (P= 0.05)	1.10	1.15	1.33

T_0: Control (RDF); T_1: RDF + soil application of micronutrient mixture@10kg/ha at 30DAS; T_2: RDF + foliar application of micronutrient mixture@1% at 30DAS; T_3: RDF + seed priming with micronutrient mixture@1% before sowing; T_4: 75% RDF + soil application of micronutrient mixture@10kg/ha at 30DAS; T_5: 75% RDF + foliar application of micronutrient mixture@1% at 30DAS; T_6: 75% RDF + seed priming with micronutrient mixture@1% before sowing; T_7: 75% RDF + soil application of micronutrient mixture@10kg/ha + humic acid@1% at 30DAS; T_8: 75% RDF + foliar application of micronutrient mixture@1% + humic acid@1% at 30DAS; T_9: 75% RDF + seed priming@1% before sowing + humic acid@1% at 30DAS; Micronutrient mixture: 12.5g $FeSO_4$, 25g $MnSO_4$, 100g $ZnSO_4$, 350g Borax and 4.5g $CuSO_4$)

Table 3. Correlation matrix of yield attributes of *kharif* maize under macronutrient levels, micronutrient mixture and humic acid

	CP	CL	CG	CWH	CW	GRC	GR	GW
CP	1							
CL	0.991**	1						
CG	0.917**	0.917**	1					
CWH	0.911**	0.919**	0.992**	1				
CW	0.897**	0.894**	0.988**	0.992**	1			
GRC	0.866**	0.874**	0.972**	0.974**	0.981**	1		
GR	0.764**	0.749**	0.873**	0.878**	0.908**	0.918**	1	
GW	0.785**	0.775**	0.877**	0.881**	0.907**	0.906**	0.974**	1

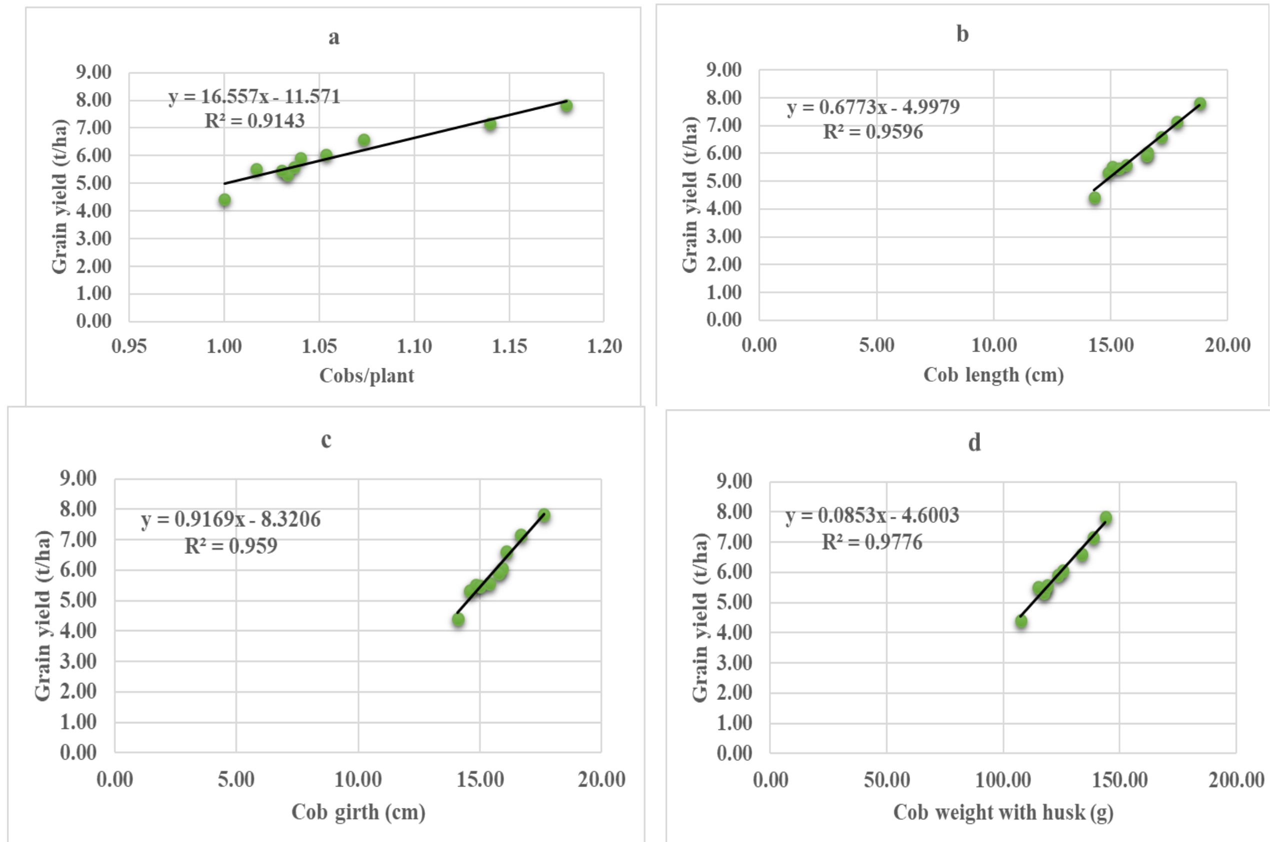
*CP: Cobs/plant, CL: Cob length, CG: Cob girth, CWH: Cob weight with husk, CW: Cob weight without husk, GRC: Grains row/cob, GR: grains/row, GW: 100 grains weight, **Highly significant*

Table 4. Effect of macronutrient levels, micronutrient mixture and humic acid on economics of *kharif* maize

Treatments	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C
T_0	55,800	1,09,130	53,330	1.96
T_1	56,952	1,23,813	66,860	2.17
T_2	56,976	1,34,930	77,954	2.37
T_3	56,034	1,13,230	57,196	2.02
T_4	55,506	1,11,940	56,434	2.02
T_5	55,530	1,14,143	58,613	2.06
T_6	54,588	90,705	36,117	1.66
T_7	57,431	1,45,988	88,556	2.54
T_8	57,455	1,59,708	1,02,253	2.78
T_9	57,038	1,21,180	64,142	2.12

T_0: Control (RDF); T_1: RDF + soil application of micronutrient mixture@10kg/ha at 30DAS; T_2: RDF + foliar application of micronutrient mixture@1% at 30DAS; T_3: RDF + seed priming with micronutrient mixture@1% before sowing; T_4: 75% RDF + soil application of micronutrient mixture@10kg/ha at 30DAS; T_5: 75% RDF + foliar application of micronutrient mixture@1% at 30DAS; T_6: 75% RDF + seed priming with micronutrient mixture@1% before sowing; T_7: 75% RDF + soil application of micronutrient mixture@10kg/ha + humic acid@1% at 30DAS; T_8: 75% RDF + foliar application of micronutrient mixture@1% + humic acid@1% at 30DAS; T_9: 75% RDF + seed priming@1% before sowing + humic acid@1% at 30DAS; Micronutrient mixture: 12.5g $FeSO_4$, 25g $MnSO_4$, 100g $ZnSO_4$, 350g Borax and 4.5g $CuSO_4$)

**Price of maize grain and stover: ₹19.75/kg and ₹500/t, respectively*


a
y = 16.557x - 11.571
R² = 0.9143
Grain yield (t/ha)
Cobs/plant
b
y = 0.6773x - 4.9979
R² = 0.9596
Grain yield (t/ha)
Cob length (cm)
c
y = 0.9169x - 8.3206
R² = 0.959
Grain yield (t/ha)
Cob girth (cm)
d
y = 0.0853x - 4.6003
R² = 0.9776
Grain yield (t/ha)
Cob weight with husk (g)

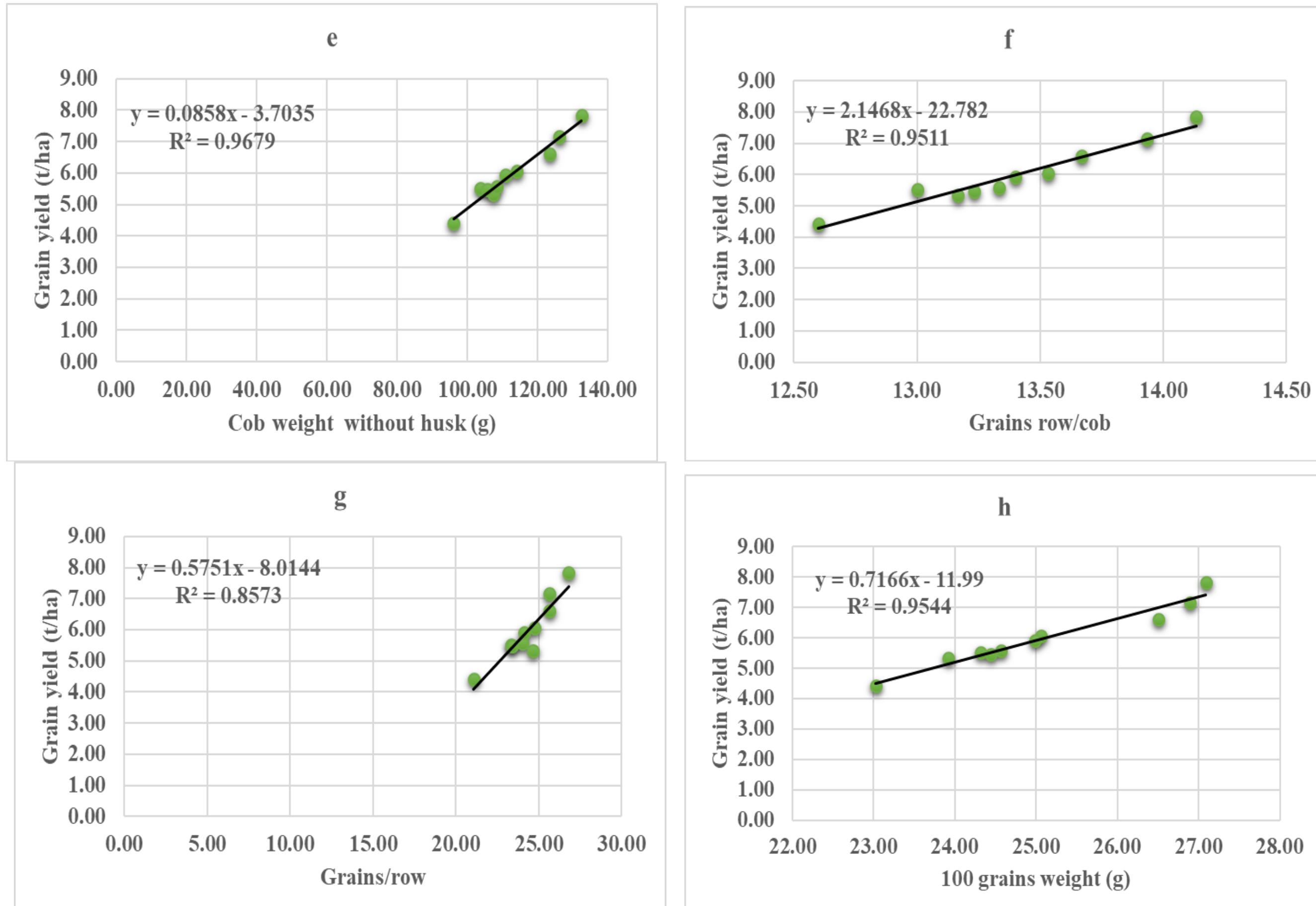


Fig. 1. Relationship between grain yield and (a) cobs/plant, (b) cob length, (c) cob girth, (d) cob weight with husk, (e) cob weight without husk, (f) grains row/cob, (g) grains/row, (h) 100 grains weight

4. CONCLUSION

Overall, the study confirmed the efficacies of micronutrient mixture as well as humic acid in *kharif* maize cultivation along with macronutrients. It indicated that combined application of organic and inorganic sources of nutrients through appropriate method of application (soil and/or foliar) as well as integration of various micronutrients with primary macronutrients are the key factors influencing *kharif* maize production. Considering the finding of the investigation, application of 75% RDF + foliar application of micronutrient mixture@1% + humic acid @1% at 30 DAS can be recommended to maize growers of Punjab, India to achieve high production and economic profitability from *kharif* maize cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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