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Growth and yield of irrigated maize (*Zea mays* L.) as influenced by mechanization and nutrient management practices

AP Sivamurugan[1], A Surendrakumar[2], C Bharathi[3]*, R Karthikeyan[3], S Pazhanivelan[1], V Manivannan[3] & P Shanmugapriya[1]

[1]Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

[2]Department of Farm Machinery, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

[3]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

*Email: bharathi.c@ tnau.ac.in

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Abstract

Maize is a dominant and promising crop grown in almost all regions throughout the year for various purposes, owing to its wide adaptability. In India, the productivity of maize is low, which can be attributed to usage of conventional varieties, inadequate supply of organic and inorganic fertilizers, low adoption of mechanization practices and the indiscriminate use of pesticides and fungicides etc. Among these factors, mechanization and nutrient management practices play a critical role in influencing productivity through supply of nutrients and ensuring timeliness of operations. Keeping in view the above facts, field experiments were conducted in the Department of Agronomy and the Department of Millets during *Kharif* seasons of 2018, 2019 and 2020 to study the growth and yield of irrigated maize as influenced by mechanization practices and nutrient management strategies. The results of mechanization experiment revealed that T_3-sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (3 days after sowing (DAS) - after irrigation) + weeding by power weeder (30 - 35 DAS) achieved higher grain yield (5549 kg ha^{-1}), net returns (Rs. 58, 158 ha^{-1}) and B:C ratio (2.66). The results of nutrient management experiments revealed that the application of 250:75:75 kg NPK/ha (100% the recommended dose of fertilizer (RDF) achieved higher grain yield (7327 kg ha^{-1}), net returns (Rs. 73518/ha) and B: C ratio (2.50) in maize (T_2).

Keywords

drip tape irrigation; inclined plate planter; nutrient management; RDF

Introduction

Conventional practices adopted for the cultivation of maize, such as land preparation, sowing, fertilizer application, weeding, irrigation, harvest and post-harvest operations demand more energy, time and cost besides drudgery (1). These agro-techniques are laborious, thus affecting the timeliness of operations and leading to drastic reduction in yield. Additionally enhanced wages must be paid to labourers during the peak season of cultivation which increases cost of production (2). Mechanization is a viable alternative to improve productivity and the net returns of farmers by ensuring timeliness of operations, judicious use of inputs and also through reduction in cost of production (3). These practices have been found to enhance productivity of crops by 15% and decrease the production cost to an extent of 20% and promote the sustainable production of crops (4). This paves the way for farmers to adopt commercial agriculture rather than subsistence farming.

The adoption of intensive agriculture during the Green revolution resulted in a remarkable enhancement in productivity of crops owing to usage of high-yielding varieties, inorganic fertilizers and other externally purchased inputs (5). This intensification of agriculture has led to the removal of larger quantities of nutrients from the soil by the crops leading to depletion of soil reserves besides posing severe effects on health of soil over the years (6). This degradation was primarily due to a complete reliance on synthetic fertilizers, pesticides, fungicides and similar inputs. Hence, an integrated nutrient management approach is necessary to achieve desirable productivity of crops without degrading soil fertility and to mitigate the adverse effects of inorganic farming. Maize (*Zea mays* L.) is grown in all seasons as it gets accustomed in conducive as well as in adverse environment (7). However, in India, the productivity is low compared to other maize dominant countries. This is due to usage of local and low-yielding varieties instead of recently released hybrids, imbalanced nutrition, periodic droughts, improper application of pesticides and fungicides and low adoption of mechanization practices (8). Considering the above facts, field experiments were conducted to study the growth and yield of irrigated maize under the influence of mechanization practices and nutrient management strategies.

Materials and Methods

Kharif (2018 and 2019)

Experiments were conducted in sandy clay loam soil during the *kharif* seasons of 2018 and 2019 at the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, to study the effect of pre-emergence herbicide application before irrigation through drip tubes and after irrigation, as well as to assess the influence of mechanization practices on the yield parameters and yield of irrigated maize. The experiments were laid out with the following treatments, which were no replicated.

	Treatments
T_1	Manual sowing in flat beds (60 × 25 cm) + spraying of pre-emergence herbicide with hand operated sprayer (3 DAS) + hand weeding (30-35 DAS)
T_2	Sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (before irrigation) by tractor mounted boom sprayer + weeding by power weeder (30 - 35 DAS),
T_3	Sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS)
T_4	Sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + weeding by power weeder twice (15 - 20 DAS and 30 - 35 DAS)

In this experiment, designer seed (TNAU Maize hybrid CO 6 coated with *Azospirillum*, phosphobacteria, imidacloprid and *Trichoderma viride*) was used for sowing in both the manual and mechanical methods. Harvest of stover by reaper and mechanical shelling of cobs were kept as common operations for all the treatments. Other crop management practices were adopted as per TNAU, crop production guide (9). Observations on weed density, weed dry weight, yield attributes, yield and efficiency of different implements were recorded. The recorded observations were statistically analyzed as per Gomez and Gomez (10).

Kharif (2018, 2019 and 2020)

Experiments were conducted in sandy clay loam soil during the *kharif* seasons of 2018, 2019 and 2020 at the Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore to assess the effect of organics and inorganics on growth and yield of maize. The experiments consisted of eleven treatments and these treatments were imposed with three replications.

	Treatments
T_1	Unmanured
T_2	250:75:75 NPK kg/ha (100% RDF),
T_3	187.5:56.25:56.25 NPK kg/ha (75% RDF),
T_4	125:37.5:37.5 NPK kg/ha (50% RDF),
T_5	Farmyard manure (FYM) 10t/ha + Biofertilizer
T_6	Maize + greengram + FYM 10 t/ha + Biofertilizer,
T_7	250:75:75 NPK kg/ha (100% RDF), + 5 t/ha FYM
T_8	187.5:56.25:56.25 NPK kg/ha (75% RDF) + 5 t/ha FYM
T_9	125:37.5:37.5 NPK kg/ha (50% RDF) + 5 t/ha FYM,
T_{10}	250:75:75 NPK kg/ha (100% RDF) + 5 kg Zinc/ha
T_{11}	FYM 5 t/ha

TNAU maize hybrid CO 6 was used for sowing in all the study years and the other agro-techniques were followed in accordance with the crop production guide of TNAU released during 2018 (9).

Growth and yield parameters namely, plant height, length and girth of cob (cm), number of grains, number of grain rows per cob and test weight (g) were recorded. The cobs and stover from the net plot were harvested for computing grain and stover yield per plot. Economics was worked out using market price of the inputs and produces. The recorded observations were statistically analyzed as per the methodology of Gomez and Gomez (10) for a randomized complete block design and critical differences were worked out at 5% probability level.

Results and Discussion

Kharif (2018 and 2019)

Effect of mechanization practices on weed density in maize

Experimental results revealed that different mechanization practices failed to influence density of grasses at 15 DAS (Table 1). However, lower density of grasses (0.88 No/m^2) was recorded in T_3- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS).In respect of sedges, T_2- sowing by inclined plate planter (75 × 20 cm-drip tape irrigation) + spraying of pre-emergence herbicide (before irrigation) by tractor mounted boom sprayer + weeding by power weeder (30 - 35 DAS) recorded lower density of 1.4 No/m^2 which was higher with T_3-sowing by inclined plate planter (75 × 20 cm-drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS) and T_4- sowing by inclined plate planter (75 × 20 cm-drip tape irrigation) + weeding by power weeder twice (15-20 DAS and 30 - 35 DAS). This was ascribed to dominance of broad-leaved weeds (BLW) which suppressed the growth of sedges leading to lower density. The results are in concurrence with previous findings (11-13). With regard to BLW, lower density (55.6 No/m^2) was recorded in T_1- manual sowing in flat beds (60 × 25 cm) +

spraying of pre-emergence herbicide with hand operated sprayer (3 DAS) + hand weeding (30-35 DAS). This was ascribed to inhibition of photosynthesis through interfering with electron transfer (14, 15) by atrazine.

At 30 DAS, T_4- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + weeding by power weeder twice (15 - 20 DAS and 30 - 35 DAS) recorded lower grassy weed density of 1.1 No/m^{2}which was significantly superior to other mechanization practices. In respect of sedges, T_3- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (before irrigation) + weeding by power weeder (30-35 DAS) recorded lower density which was comparable with T_4- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + weeding by power weeder twice (15 - 20 DAS and 30 - 35 DAS) and T_3- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS). Lower density of grasses and sedges recorded in these treatments might be due to successful and proficient weed control through disruption in photosynthetic activity through electron transfer system on application of atrazine and power weeder, respectively. The results confirm the previous experiments (16-18). On 30 DAS, density of BLW was not influenced by the treatments. However, T_3- sowing by inclined plate planter (75 × 20 cm – drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS) recorded lower density. Mechanization practices did not evince significant influence on density of grasses, sedges and broad-leaved weeds at harvest.

Effect of mechanization practices on weed dry weight in maize

Mechanization practices failed to exert remarkable influence (Table 2) on dry weight of grasses, sedges and broad-leaved weeds (BLW). Nevertheless, T_3- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre=emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS) recorded lower dry weight of grasses, sedges and BLW at 15 DAS and 30 DAS. Lower dry weight of weeds realized in this treatment was ascribed to higher efficacy and persistence of atrazine, which would have inhibited growth of weeds. Similar findings were previously documented (19, 20). At harvest, grassy weed density was not significantly influenced by various mechanization practices. With respect to BLW, T_3- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS) recorded lower dry weight of 8.0 g/m^2 which was comparable with T_1- manual sowing in flat beds (60 × 25 cm) + spraying of pre-emergence herbicide with hand operated sprayer (3 DAS) + hand weeding (30-35 DAS) and T_4- sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + weeding by power weeder twice (15 - 20 DAS and 30 - 35 DAS). The lower dry matter recorded in this treatment might be due to lower density of weeds as further germination of weeds was averted and also efficient removal of weeds on application of atrazine and power weeder. The results corroborate with the previous findings (21, 22).

Effect of mechanization on yield parameters, yield and economics of maize

Mechanization practices failed to exert a significant influence on yield parameters in maize (Table 3). However, T_1-manual sowing in flat beds (60 × 25 cm) + spraying of pre-emergence herbicide with hand operated sprayer (3 DAS) + hand weeding (30-35 DAS), T_1 recorded higher cob length (16.7 cm), cob girth (15.3 cm), grains/row (31.5), number of rows/cob (15.1) and 100 seed weight (38.0 g) in comparison with the other treatments. This was followed by T_3-sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS). This was ascribed to reduction in density of weeds which favoured more accumulation of photosynthates resulting in a significant improvement in yield parameters. The result confirms the findings of earlier study (23, 24).

In respect of yield, higher grain yield of 5674 kg ha^{-1} was achieved under T_1-manual sowing in flat beds (60 × 25 cm) + spraying of pre-emergence herbicide with hand operated sprayer (3 DAS) + hand weeding (30-35 DAS). This was on par with T_3-sowing by inclined plate planter (75 × 20 cm - drip tape

Table 1. Effect of mechanization practices on weed density in maize

Treatments	Weed density (No/m^2) – Mean of 2 years								
	15 DAS			30 DAS			At harvest		
	Grasses	Sedges	Broad Leaved Weed	Grasses	Sedges	Broad Leaved Weed	Grasses	Sedges	Broad Leaved Weed
T_1	10.8	2.4	55.6	33.8	1.1	243.8	26.2	0	13.6
T_2	8.5	1.4	95.6	18.1	0	309.3	15.7	0	14.1
T_3	0.88	1.6	80.5	11.2	0.4	132.8	23.5	0	7.3
T_4	9.0	1.7	138.1	1.1	0.3	161.9	19.9	0	8.8
CD (p=0.05)	**NS**	**0.59**	**19.8**	**9.5**	**0.5**	**NS**	**NS**	**0**	**NS**

NS - Non significant

Table 2. Effect of mechanization practices on weed dry weight in maize

Treatments	Weed dry weight (g/m^2) – Mean of 2 years								
	15 DAS			30 DAS			At harvest		
	Grasses	Sedges	Broad Leaved Weed	Grasses	Sedges	Broad Leaved Weed	Grasses	Sedges	Broad Leaved Weed
T_1	9.1	1.2	17.4	30.1	0.8	95.3	20.2	0	23.4
T_2	5.1	0.6	30.7	10.4	0	124.6	13.4	0	34.5
T_3	0.7	0.6	25.9	6.2	0.3	52.8	20.4	0	8.0
T_4	5.4	0.7	45.4	0.7	0.2	67.0	18.3	0	28.4
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0**	**25.6**

NS - Non significant

Table 3. Effect of mechanization practices on yield attributes, yield and economics of maize

	Mean of 2 years							
Treatments	**Cob length (cm)**	**Cob girth (cm)**	**Grains / row**	**No. of rows/cob**	**100 seed weight (g)**	**Grain yield (kg/ha)**	**Net returns (Rs/ha)**	**B:C**
T_1	16.7	15.3	31.5	15.1	38.0	5674	53741	2.33
T_2	14.5	13.3	27.9	14.6	37.3	4989	50100	2.43
T_3	14.9	13.6	28.8	14.8	37.5	5549	58158	2.66
T_4	14.0	13.0	27	14.3	36.7	4486	42996	2.24
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**994**		

NS - Non significant

irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30 - 35 DAS) and T_2-sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (before irrigation) + weeding by power weeder (30 - 35 DAS). This was ascribed to effective utilization of natural resources, such as water, space and light as a result of low crop weed competition leading to remarkable enhancement in growth and yield attributes resulting in higher yield in this treatment. The results are in conformity with the previous field experiments (25-28).

T_4-Sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + weeding by power weeder twice (15 - 20 DAS and 30 - 35 DAS) recorded the lowest yield of 4486 kg ha^{-1}. This might be due to higher density of weeds which utilized more space, light, water and nutrients resulting in low yield (29, 30). In respect of economics, T_3-sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + spraying of pre-emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30-35 DAS) registered higher net returns (Rs. 58158/ha) and B:C ratio (2.66) in comparison with the other treatments as evidenced by lower cost incurred in weed control through use of atrazine and power weeder. Similar results were obtained from the previous study (31, 32).

Kharif (2018, 2019 and 2020)

Effect of organics and inorganics on growth, yield parameters and yield of maize

Data on pooled analysis of three years revealed that plant height was not significantly influenced on the application of organics and inorganics (Table 4). However, higher plant height of 245.5 cm at harvest was recorded on application of 250:75:75 NPK kg/ha (100% RDF) + 5 t/ha FYM (T_7). This was ascribed to improved physical, chemical and biological properties of soil which in turn supplied adequate quantities of nutrients to the plant. This promotes cell division, internodal elongation and increased plant height. Similar trends were previously documented (33). Yield parameters except cob length were not considerably influenced by the treatments. Among them, higher cob length (20.3 cm) was recorded under 250:75:75 NPK kg/ha (100% RDF) + 5 t/ha FYM (T_7). Application of inorganic fertilizers and organic manures in excess amount resulted in the improved nutrient availability in soil, which favoured enhanced absorption, translocation of nutrients and assimilation by the crop resulted in increased cob length. The result confirms the previous findings (34, 35). The same treatment resulted in improvement of other yield parameters also. This was due to more accumulation of photosynthates owing to lower competition for nutrients. The results are in concurrence with the previous experimental results (36).

Higher grain yield of 7401 kg ha^{-1} was registered through combined application of 250:75:75 NPK kg/ha (100% RDF) + 5 t/ha FYM (T_7). This treatment was on par with T_{10}, T_2, T_8 and T_3. This was ascribed to considerable improvement in yield parameters owing to adequate nutrient supply. The results confirm the earlier findings (37). The lowest yield of 3502 kg ha^{-1} was recorded in unmanured treatment. In respect of economics, higher net returns of Rs. 73518/ha with a B: C ratio of 2.50 was registered under T_2- 250:75:75 NPK kg/ha (100% RDF).

Table 4. Effect of organics and inorganics on growth, yield parameters, yield and economics of maize (Mean of 3 years)

Treatments	**Plant height (cm) at harvest**	**Cob length (cm)**	**Cob girth (cm)**	**No. of grain rows/ cob**	**No. of grains/ row**	**100 seed weight (g)**	**Grain yield (kg/ha)**	**Net returns (Rs/ha)**	**B:C ratio**
T_1	235.2	16.3	14.0	13.8	32.1	30.8	3502	18816	1.47
T_2	243.6	19.8	16.1	14.4	34.6	38.2	7327	73518	2.50
T_3	241.4	19.4	16.0	14.2	33.9	37.0	6833	67025	2.43
T_4	238.5	18.3	15.8	14.2	33.1	36.0	5931	53771	2.20
T_5	236.4	17.2	14.3	14.1	32.8	32.8	4312	23429	1.49
T_6	236.8	17.4	14.2	14.1	32.8	32.7	4777	27442	1.54
T_7	245.5	20.3	16.5	14.7	35.4	38.8	7401	71122	2.35
T_8	242.8	19.5	16.0	14.4	34.4	37.1	6913	64691	2.28
T_9	238.8	18.4	15.9	14.2	33.4	36.5	6029	51704	2.06
T_{10}	244.3	20.0	16.2	14.6	35.1	38.4	7351	72303	2.43
T_{11}	236.0	16.6	14.0	14.0	32.4	32.4	3757	18033	1.40
CD (p=0.05)	**NS**	**2.7**	**NS**	**NS**	**NS**	**NS**	**849**		

NS - Non significant

Conclusion

The results of experiment on mechanization revealed that sowing by inclined plate planter (75 × 20 cm - drip tape irrigation) + Spraying of pre emergence herbicide (3 DAS- after irrigation) + weeding by power weeder (30-35 DAS) recorded higher grain yield (5549 kg ha^{-1}), net returns (Rs. 58158 ha^{-1}) and B:C ratio (2.66). Experiments on nutrient management revealed that application of 100% RDF (250:75:75 Kg NPK/ha) recorded higher grain yield (7327 kg ha^{-1}), net returns (Rs. 73518/ha) and B:C ratio (2.50) in maize.

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Authors' Contributions

APS, AS and RK were responsible for conducting field experiments, preparation and communication of manuscript, SP has conceptualized the work and provided guidance for the experiments and CB, VM and PS have provided the study materials, reviewed and edited the manuscript

Compliance with Ethical Standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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