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Effect of Tillage, Crop Residue Management and Nutrient Levels on Growth and Yield of Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field study was conducted during *rabi* season of 2022 at Maize Research Centre, Professor Jayashankar Telangana State Agriculture University, Agricultural Research Institute, Rajendranagar, Hyderabad, Telangana. The experiment comprised of 12 treatment combinations

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laid out in a split–plot design with three replications. The main–plot treatments included four different tillage practices:M_1-Conventional tillage (Plough + Cultivator + Rotovator), M_2-Residue incorporation (After 10 days of spreading the haulms, only rotovator was run), M_3- Residue incorporation (After spreading the haulms, microbial consortium was sprayed and after 10 days only rotovator was run) and M_4- Zero-tillage (only microbial consortium was sprayed on the haulms). Sub–plot treatments included three nutrient levels: N_1- 100% RDF (240-80-80 N-P_2O_5-K_2O kg ha^{-1}), N_2: 100% RDN & P and 50% RDK (240-80-40 N-P_2O_5-K_2O kg ha^{-1}), and N_3: 87.5% of RDN, 75% RDP and 75% RDK (210-60-60 N-P_2O_5-K_2O kg ha^{-1}). Results revealed that, among the tillage practices, residue incorporation (M_3) had recorded significantly higher growth attributes like plant height, leaf area, dry matter production and chlorophyll content (SPAD) at 30, 60 DAS and at harvest stages and yield of maize and it was on par with zero-tillage (M_4) whereas all the parameters were significantly lower in conventional tillage (M_1). Among the different nutrient levels, N_1(100% RDF) had shown significantly superior performance in terms of growth attributes and yield of maize and it was on par with N_2 (100% RDN & P and 50% RDK) whereas N_3(87.5% of RDN, 75% RDP and 75% RDK) recorded significantly lower growth attributes and yield of maize .The interaction effect due to tillage and nutrient levels on plant height, leaf area, dry matter production, chlorophyll content (SPAD) at 30, 60 DAS and at harvest and yield was non- significant.

Keywords: Maize; microbial consortium; nutrient levels; residue incorporation; tillage

1. INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in India after rice and wheat and is grown in wide range of environments. It has enormous potential to provide food, feed nutritional security, and qualifies as a potential crop for doubling farmer's income. Maize is a less water-demanding crop and substantial savings in water and power usage could reach up to 90% and 70%, respectively, when compared to paddy cultivation [1].

The area under maize in India accounts to 10.04 M ha with a production and productivity of 33.62 MMT& 3349 kg ha^{-1} respectively and contributed to 9% of the national food basket [2].

Globally, sustainable management of agricultural waste is a great challenge, especially in developing nations like India with a burgeoning population, production rate and economic growth [3]. India generates more than 500 million tons of crop residues annually [4]. Burning of crop residues causes air pollution and leads to loss of soil biota, huge biomass, organic carbon and plant nutrients. Approximately 80– 90% of N, 25% of P, 20% of K and 50% of S present in crop residues are lost in the form of various gaseous and particulate matters, resulting in atmospheric pollution and global warming [5].

Recycling of crop residues in the soil is a promising option for replenishing soil fertility, improving physico-chemical properties and sustaining crop yields [6]. However, additional resources such as water, nutrients and bio-inoculum are required to promote the decomposition of crop residue under in situ decomposition [7]. Among the different crop residues legume crops provide sustainability by enriching soil fertility and increasing system productivity (substantial residual effects) and monetary returns [8].

Maize being an exhaustive crop has very high nutrient demand and its productivity mainly depends upon nutrient management systems. The recent energy crisis, high fertilizer cost and low purchasing power of the farming community have made it necessary to rethink alternatives and to enhance crop yield per unit of applied nutrients by providing a better physical, chemical and microbial environment [9].

Incorporation of leguminous (Soybean, cowpea, chickpea etc.), crop residues has been shown to improve the soil's physical properties, such as water-holding capacity, soil permeability etc. and inclusion of leguminous crop residues also increases crop growth and productivity by enhancing the availability of nutrients for the root zone of the succeeding cereals (Maize and sorghum) [10].

2. MATERIALS AND METHODS

This experiment was conducted at Agricultural Research Institute (ARI), Maize Research Centre, Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad, Telangana during *Rabi*, 2022. The experimental site was geographically located at 17° 3' N latitude,78° 39' E longitude and an altitude of 494 m above mean sea level (MSL) and 1 km away from IIMR (Indian Institute of Millets Research). According to Troll's climatic classification, it falls under Semi- Arid Tropical region (SAT). The experimental site was in the Southern Telangana Agro-Climatic Zone. The experiment comprised 12 treatment combinations laid out in a split–plot design with three replications. The main–plot treatments included four different tillage and residue management practices (residue used was soybean haulm):M_1-Conventional tillage (Plough + Cultivator + Rotovator), M_2- Residue incorporation (After 10 days of spreading the haulms, only rotovator was run), M_3- Residue incorporation (After spreading the haulms, microbial consortium was sprayed and after 10 days, only rotovator was run) and M_4- Zero-tillage (Only microbial consortium was sprayed on the haulms). A microbial consortium developed by PJTSAU was used which comprises Trichoderma viride, Phenerocheta chrysosporium and Aspergillus niger @ 2% spray to the weight of added residue. Sub–plot treatments included three nutrient levels: N_1-100% RDF (240-80-80 N-P_2O_5-K_2O kg ha^{-1}), N_2: 100% RDN & P and 50% RDK (240-80-40 N-P_2O_5-K_2O kg ha^{-1}), and N_3: 87.5% of RDN, 75% RDP and 75% RDK (210-60-60 N-P_2O_5-K_2O kg ha^{-1}). Recommended nitrogen was applied to the maize crop in three (3) splits at the time of sowing (basal), knee-high and flowering stages in the form of urea as per treatments. Recommended phosphorus (80kg $P_2O_5ha^{-1}$) was applied in a single dose at the time of sowing in the form of SSP as per the treatments and recommended potassium (80kgK_2Oha^{-1}) was applied to the maize crop in two (2) splits at the time of sowing (basal) and flowering stages in the form of muriate of potash as per treatments. The soil type of the experimental site was Vertisol. The soil of the experimental site was medium clay loam, slightly alkaline, low in organic carbon and nitrogen, high in available phosphorus and potassium. The maize hybrid DHM-121 was sown on 15th November 2022 with a seed rate of 20kg ha^{-1}. The spacing used was 60×20 cm. The climate of the experimental region is semi-arid (dry). The weekly mean maximum temperature ranged from 27.4°C to 33.9°C, with an average of 30.8°C, throughout the crop growth period, while the weekly mean minimum temperature ranged from 11.2°C to 18.9°C, with an average of 15.1°C. In terms of relative humidity, the weekly mean RH-I (morning) ranged from 74.6% to 97.1%, with an average of 84%, while the RH-II (afternoon) ranged from 17.4% to 63.9%, with an average of 36.6%. Using the USWB Class - A open pan evaporimeter, the weekly mean bright sunshine hours per day ranged from 3.6 to 10.1 hours, with an average of 7.6 hours. Weekly mean evaporation ranged from 2.3 to 5.3 mm per day, with an average of 3.7 mm per day. The wind speed stretched from 2.0 to 4.1 km hr^{-1}. No rainfall was observed during the crop growth period. The effect of tillage and nutrient levels on plant height, leaf area, dry matter accumulation, chlorophyll content (SPAD) at 30, 60 DAS and at harvest stages and grain yield has been recorded.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height (cm)

Data pertaining to plant height (cm) as influenced by tillage and nutrient levels is presented in Table 1.

A perusal of the data indicated that the tillage had a significant influence on the plant height at 30, 60 DAS and at harvest stages of maize. Among the treatments, M_3 (residue incorporation along with microbial consortium spray) recorded significantly higher plant height at 30, 60 DAS and at harvest stages (65, 165 and 253 cm respectively) and it was on par with M_4 (zero tillage) (63, 160 and 250 respectively). However, significantly lowest plant height was with M_1 (conventional tillage) (56, 150 and 234 respectively). The improvement in plant height of maize with the incorporation of legume crop residues was due to the accumulation of a high amount of nutrients through the addition of residues which was returned to the soil. In addition, spraying of microbial consortium helped in quicker decomposition and mineralization of residues and in turn quicker release of nutrients. As residues have contributed to the high amount of nutrients to the succeeding maize crop the results were visible at later stages also. The present findings are in corroboration with the reports of Egbe and Ali [11], Ammaji [12] and Ndiso et al. [13].

Nutrient levels have shown a significant influence on plant height of maize at 30, 60 DAS and at harvest stages. Application of 100% RDF (N_1) recorded significantly highest plant height at 30, 60 DAS and at harvest stages (63, 163 and 250 cm respectively) and it was on par with (N_2) i.e., 100% RDN & P and 50% RDK (61, 158 and 246 cm respectively) whereas significantly lowest plant height was with (N_3) i.e., 87.5% of RDN, 75% RDP and 75% RDK (56, 151 and 234 cm respectively). The increase in plant height was due to adequate availability of NPK attributed to a better nutritional environment for plant growth at the active vegetative stage. This resulted in enhancement in cell multiplication, cell elongation and cell expansion in the plant body which further helped in increasing plant height at all the stages. The results of the present investigation are also in agreement with the findings of Shanti et al. [14], Shivay et al. [15], Singh et al. [16] Bakht et al. [17] and De Vita et al. [18].

The interaction effect due to tillage and nutrient levels on plant height of maize at 30, 60 DAS and at harvest was found non-significant.

3.1.2 Leaf area(cm^2)

Data pertaining to leaf area (cm^2) as influenced by tillage and nutrient levels is presented in Table 1.

The experimental findings demonstrated that tillage had a significant influence on the leaf area of maize. Among the various treatment combinations evaluated, M_3 (residue incorporation along with microbial consortium spray) exhibited significantly elevated leaf area at 30, 60 DAS and at harvest stages (101.83, 384.39 and 397.91cm^2 respectively) and this was on par with M_4 (zero tillage) (98.10, 378.62 and 391.14cm^2 respectively). However, the significantly lowest leaf area was with M_1 (conventional tillage) (94.84, 367.97 and 382.72 cm^2 respectively). The better performance with M_3 treatment was due to the availability of residual soil nutrients by the incorporation of soybean residue and microbial consortium sprayed on the haulms. This helped in improving photosynthetic capacity and the source strength in the source-sink relationship. The increased nutrient availability seemed to prolong the vegetative phase of the plant and also decreased the rate of senescence which led to more leaf area. Similar results were also reported by Uhart and Andrade [19], Cheruiyot et al. [20], Beary et al. [21] and Ali et al. [22].

Various nutrient levels have exerted significant influence on the leaf area of maize. Application of 100% RDF (N_1) resulted in significantly highest leaf area at 30, 60 DAS and at harvest stages (99.85, 381.97 and 396.38cm^2 respectively) and it was on par with (N_2) i.e., 100% RDN & P and 50% RDK (98.38, 376.08 and 389.75cm^2 respectively), whereas significantly lowest leaf area was recorded with (N_3) i.e., 87.5% of RDN, 75% RDP and 75% RDK (94.95, 367.76 and 380.09cm^2 respectively). An adequate supply of nutrients had helped the maize plants to increase their growth, which in turn put forth more photosynthetic surface thus resulting in the production of a greater number of leaves per plant with a larger area. Increased leaf area with each increment in the level of N application was due to the role of nitrogen in increasing cell division and cell elongation. The positive response of nutrients on leaf area across different soils and regions was also reported by Shanti et al. [14], Patel et al. [23], Bindhani et al. [24], Hokmalipour and Darbandi [25], Imran et al. [26], Singh et al. [27] and Meena et al. [28].

The interaction effect due to tillage and nutrient levels on leaf area at 30, 60 DAS and at harvest was non-significant.

3.1.3 Dry matter production (kg ha^{-1})

Data pertaining to dry matter production (kg ha^{-1}) as influenced by tillage and nutrient levels is presented in Table 2. Examination of the data revealed that tillage exerted a substantial impact on the dry matter production of maize. Within the various experimental treatments, M_3 (residue incorporation along with microbial consortium spray) achieved significantly superior dry matter production at 30, 60 DAS and at harvest stages (565, 3718 and 15396 kg ha^{-1} respectively) and it exhibited comparable results with M_4 (zero tillage) (553, 3669 and 14913kg ha^{-1} respectively). Conversely, treatment M_1 (conventional tillage) exhibited markedly lower dry matter production (494, 3390 and 14055 kg ha^{-1}respectively). The higher dry matter accumulation in maize with preceding soybean was attributed to the biological fixation of nitrogen by the soybean which resulted in a continuous supply of nitrogen during mineralization of soybean crop residues. Also, spraying of microbial consortium helped in quicker decomposition and mineralization of soybean residues and release of nutrients to the succeeding maize which enhanced the dry matter production when compared to residue removed plots. Similar findings were observed by Rahim et al. [29], Cheruiyot et al. [20], Beary et al. [22], Sangakkara et al. [30], Nyalemegba and Osakpa [31], Tamiru Hirpa [32] and Shah et al. [33].

Application of 100% RDF (N_1) recorded significantly highest dry matter production at 30, 60 DAS and at harvest stages (559, 3708 and 15272kg ha^{-1} respectively) and it was on par with (N_2) i.e., 100% RDN & P and 50% RDK (550, 3617 and 15001kg ha^{-1} respectively) whereas significantly lowest dry matter production was with (N_3) i.e., 87.5% of RDN, 75% RDP and 75% RDK (489, 3350 and 13904kg ha^{-1} respectively). Higher nutrient doses increase the leaf area which leads to higher rates of photosynthesis and more assimilation of photosynthates, thus increasing dry matter production. Moreover, nitrogen is the constituent of proteins and is also involved in many physiological reactions, thereby, increasing dry matter production. Similar results were reported by Shanti et al. [14], Bangarwa et al. [34], Meena et al. [35], Rekha [36] and Singh et al. [9].

The interaction effect due to tillage and nutrient levels on dry matter production at 30, 60 DAS and at harvest was non-significant.

3.1.4 Chlorophyll content (%) (SPAD)

Data pertaining to chlorophyll content (%) as influenced by tillage and nutrient levels is presented in Table 2. The experimental results indicated that the chlorophyll content of maize was significantly influenced by tillage. Among the treatments, M_3 (residue incorporation along with microbial consortium spray) recorded significantly highest chlorophyll content at 30, 60 DAS and at harvest stages (36.2, 49.7 and 20 % respectively) and it was on par with M_4 (zero tillage) (34.7, 497.5 and19.2 % respectively). However, the significantly lowest chlorophyll content was with M_1 (conventional tillage) (32.1, 44.5 and 15.1% respectively). Soybean crop has the ability to nodulate and fix atmospheric nitrogen and converts atmospheric nitrogen into a plant–usable form. Incorporation of soybean residue along with microbial consortium spraying enhanced the aeration and better physico-chemical environment in soil by plants had higher uptake of all essential nutrients particularly those required for chlorophyll synthesis. Similar results of higher chlorophyll content were reported by Beary et al. [21], Gholizadeh et al. [37], Hokmalipour and Darbandi [25], Rekha [36], Singh et al. [9], Meena et al. [28] and Xie et al. [38].

Diverse nutrient levels have exhibited a pronounced impact on the chlorophyll content in maize. Application of 100% RDF (N_1) exhibited a significant increase of chlorophyll content at 30, 60 DAS and at harvest stages (35.8, 49.1 and 19.8% respectively) and it was on par with (N_2) i.e., 100% RDN & P and 50% RDK (34.7, 47.9 and 19.1% respectively). In contrast, the chlorophyll content was notably lower with treatment (N_3) i.e., 87.5% of RDN, 75% RDP and 75% RDK (31.6, 43.9 and 14.7% respectively). Increased chlorophyll content with increasing nutrients, especially nitrogen was because of the direct involvement of nitrogen as a constituent of protein and chlorophyll molecules. Nitrogen is the major constituent of chlorophyll therefore increases in nitrogen availability lead to an increase in chlorophyll content. Similar results of higher chlorophyll content were reported by Subramanian and Janardan, [39], Hokmalipour and Darbandi [25], Baharvand et al. [40], Rekha [36], Singh et al. [16] and Meena et al. [28].

The interaction effect due to tillage and nutrient levels on chlorophyll content at 30, 60 DAS and at harvest was non-significant.

3.1.5 Grain yield (kg ha^{-1})

Data pertaining to grain yield (kg ha^{-1}) as influenced by tillage and nutrient levels is presented in Table 2. The experimental findings revealed that tillage exerted a significant impact on the grain yield of maize. Within the various treatments, M_3 (residue incorporation along with microbial consortium spray) recorded significantly the highest grain yield (9239 kg ha^{-1}) but, it was on par with M_4 (zero tillage) (8896 kg ha^{-1}). However, the significantly lowest grain yield was with M_1 (conventional tillage) (8340 kg ha^{-1}). Incorporation of the residues after picking the economic yield of soybean interacted positively with the soil and the release of nutrients enabled the maize to get ensured and continuous nutrient supply during the entire crop growth period. In addition, spraying of microbial consortium helped in quicker decomposition and mineralization of residues which had coincided with the nutrient-demanding growth stages of succeeding maize. This contributed to the better growth, yield attributes and ultimately the grain yield of maize over no residue incorporation. The present findings are with the results reported by McDonalgh et al. [41], Bahl and Pasricha [42], Cheruiyot et al. [20], Kouyate et al. [43], Beary et al. [21], Mubarak et al. [44], Sidhu et al. [45], Okito et al. [46], Sakonnakhon et al. [47], Shafi et al. [48], Adeboye [49], Okonofua et al. [50], Lelei et al. [51], Egbe and Ali [11], Amusan et al. [52] and Arif et al. [53], Ammaji [12], Rajkumara et al. [54] and Shah et al. [33].

Table 1. Plant height and leaf area of maize at different intervals as influenced by tillage and nutrient levels

Treatments	Plant Height (cm)			Leaf Area (cm^2)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Main plots: Tillage						
M_1: Conventional tillage	56	150	234	94.84	367.97	382.72
M_2: Residue incorporation	57	153	236	96.14	370.1	383.19
M_3: Residue incorporation (Residue incorporation along with microbial consortium spray)	65	165	253	101.83	384.39	397.91
M_4: Zero-tillage	63	160	250	98.1	378.62	391.14
SE.m ±	1.29	2.32	4.05	1.26	3.58	3.82
CD (p=0.05)	4	8	12	4.34	12.39	13.2
Sub plots: Nutrient levels						
N_1: 100% RDF	63	163	250	99.85	381.97	396.38
N_2: 100% RDN & P and 50% RDK	61	158	246	98.38	376.08	389.75
N_3: 87.5% of RDN, 75% RDP and 75% RDK	56	151	234	94.95	367.76	380.09
SE.m ±	2	3.04	4.33	1.4	4.5	4.38
CD (p=0.05)	5	9	12	4.17	13.39	13.01
Interaction						
Nutrient levels at same level of tillage						
SE.m ±	5.65	9.49	13.23	4.25	12.36	12.79
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Tillage at same level of nutrient levels						
SE.m ±	7.32	12.11	16.99	5.01	14.25	16.31
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Table 2. Dry matter production, chlorophyll content and grain yield of maize at different intervals as influenced by tillage and nutrient levels

Treatments	Dry matter (kg ha^{-1})			Chlorophyll content (%) (SPAD)			Grain yield (Kg ha^{-1})
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	
Main plots: Tillage							
M_1: Conventional tillage	494	3390	14055	32.1	44.5	15.1	8340
M_2: Residue incorporation	519	3458	14538	33.2	46	17	8542
M_3: Residue incorporation (Residue incorporation along with microbial consortium spray)	565	3718	15396	36.2	49.7	20	9239
M_4: Zero-tillage	553	3669	14913	34.7	47.5	19.2	8896
SE.m ±	9.31	70.32	212.57	0.57	0.71	0.3	166.28
CD (p=0.05)	32	243	735	1.9	2.4	1.0	575
Sub plots: Nutrient levels							
N_1: 100% RDF	559	3708	15272	35.8	49.1	19.8	9140
N_2: 100% RDN & P and 50% RDK	550	3617	15001	34.7	47.9	19.1	8930
N_3: 87.5% of RDN, 75% RDP and 75% RDK	489	3350	13904	31.6	43.9	14.7	8193
SE.m ±	12.25	109.28	279.15	0.84	1.2	0.37	195.44
CD (p=0.05)	36	324	830	2.5	3.5	1.1	581
Interaction							
Nutrient levels at same level of tillage							
SE.m ±	44.09	269.66	872.22	2.65	3.41	2.63	592.72
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS
Tillage at same level of nutrient levels							
SE.m ±	76.14	369.97	1438.85	4.3	5.44	5.52	986.91
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

Various nutrient levels have exhibited a notable influence on the grain yield of maize at the time of harvest. Application of 100% RDF (N_1) recorded significantly highest grain yield (9140 kg ha^{-1}) and it was on par with (N_2) i.e., 100% RDN & P and 50% RDK (8930 kg ha^{-1}) whereas significantly lowest grain yield was with (N_3) 87.5% of RDN, 75% RDP and 75% RDK (8193kg ha^{-1}). The favorable response and advantageous outcomes resulting from the increased nutrient application on grain yield can be attributed to the enhanced availability of essential nutrients necessary for crop growth. This reflected in overall improvement in crop growth in terms of more leaf area and dry matter which helped in the preparation of more photosynthates and translocated them to the sink. In addition to these, increasing the level of fertilization improves the cation exchange capacity of plant roots and thus makes them more efficient in absorbing nutrient ions. All these reflected in an increase in various yield attributes which finally reflected in higher grain yield. The present findings are with the results reported by Chauhan [55], Khan et al. [56], Raskar et al. [57], Meena et al. [28], Imran et al. [26], Singh et al. [27], Meena et al. [28] and Sindhi et al. (2016).

The interaction effect due to tillage and nutrient levels on grain yield (kg ha^{-1}) of maize at harvest was found non-significant.

4. CONCLUSION

Tillage practices and nutrient levels have shown a significant impact on the growth and yield of maize. Residue incorporation with the microbial consortium (M_3) and 100% recommended dose of fertilizer (N_1) to maize consistently leads to significantly taller plants, larger leaf area, higher dry matter production, increased chlorophyll content and higher grain yield. Conversely, conventional tillage (M_1) and reduced nutrient levels (N_3) resulted in less favourable outcomes. These findings underscore the importance of sustainable practices and proper nutrient management in optimizing maize crop yields and quality. Implementing residue incorporation and balanced nutrient application holds promise for improving maize cultivation and food security, though further research is needed for broader validation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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