

Growth, yield and nutrient uptake of maize (*Zea mays*) as influenced by tillage and potassium management under conservation agriculture

AMARESH PRADHAN¹, S.L. MEENA² AND U.K. BEHERA³

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received : October 2017; Revised accepted : April 2018

ABSTRACT

A field experiment was carried out during the rainy (*khariif*) season (July–October) of 2016 at the research farm, New Delhi, to study the effect of time of K application on the performance of maize (*Zea mays* L.) under conservation agriculture. The maximum values of yield-attributing characters, viz. cob length (16.3 cm), cob girth (13.6 cm), cob weight (5.6 t/ha), grain rows/cob (13.7), grains/cob (3,567) and test weight (215 g) in maize were recorded with ZT – bed + residue followed by zero tillage (ZT) + residue and conservation tillage (CT)–No residue. The treatment, K₂ [half recommended dose (RD) at basal and half at tasseling] showed significantly higher values of yield attributes than all other treatments. The highest grain (4.66 t/ha) and stover (9.51 t/ha) yields were recorded in ZT – bed + residue over ZT + residue and CT – No residue. Half dose of K at sowing + half at tasseling recorded significantly higher grain (4.46 t/ha) and stover (8.65 t/ha) yield than other treatments in subplots which are at par with one-third at sowing + one-third at knee high (30 days after sowing) + one-third at tasseling. The yield improvement with ZT – bed + residue was 11.21% over CT–No residue and 7.37% over ZT + residue. ZT – bed + residue registered significantly higher N, P and K content in seed and stover and uptake during the period of study followed by ZT + residue and CT – No residue. The total N (119 kg/ha), P (27 kg/ha) and K uptake (181 kg/ha) were maximum with ZT – bed + residue which was significantly higher than ZT + residue and CT – No residue. Among the timing of K application practices, higher N, P and K content in grain, stover and total uptake in maize was observed in half at sowing + half at tasseling, which was statistically at par with one-third at sowing + one-third at knee high (30 days after sowing) + one-third at tasseling but significantly higher than recommended dose as basal (60 kg K₂O/ha).

Key words : Maize, Potassium application, Residue management, Split dose, Tillage

Maize is the third most important food crop after rice and wheat in India, mainly grown during the rainy (*khariif*) season which covers 85% of the total area under maize. As maize is a nutrient-exhaustive crop, it requires better nutrient-management practices to express its full potential. There is a growing evidence of increasing deficiency of potassium (K) as a result of imbalanced use of nitrogen (N) and phosphorus (P). The results of long-term experiments clearly demonstrated that mining of soil K occurred with NP and even with NPK application. This degradation of the land-resource base has caused crop yields and factor productivities to decline and promoted the search for an alternative paradigm that is ecologically sustainable as

well as profitable (Farooq and Siddique, 2014). The solution to above problems may lie in conservation agriculture (CA). Crop straw is fed to cattle, burnt for fuel, or used as building material leaving little for soil incorporation. As a result soil organic matter levels are declining in these cropping systems which can have serious implications for soil health (Jat *et al.*, 2016). In CA, application of fertilizers has emerged as an issue due to the fact that under CA the residue application may hinder the utilization of applied fertilizer. These factors must be considered to carry out new farming practices like CA-based potassium-management practice that can increase system yields, maintain soil health, reduce environmental pollution. Further, it may reduce investment on application of high costly K fertilizer by incorporating crop residue in zero-till CA. However, no detailed studies have been conducted to know the time of K application in maize under CA. So considering these facts in view, an experiment was conducted to study effect of time of K application and tillage management on perfor-

Based on a part of M.Sc. Thesis of the first author, submitted to the ICAR-Indian Agricultural Research Institute, New Delhi, in 2017 (unpublished)

²Corresponding author's Email: dr_slmeena@yahoo.co.in

¹Ph.D. Scholar, ^{2,3}Principal Scientist, Division of Agronomy

mance of maize under CA and evaluate the changes in soil properties due to influence of CA practices.

The experiment was conducted on sandy clay loam soil of the ICAR–Indian Agricultural Research Institute, New Delhi (28°38' N, 77° 11' E and 228 m above the mean sea-level). The soil was low in organic carbon, available N, available P and high in available K concentration, with pH 7.9. The experiment was laid out in a split-plot design with 3 main-plot treatments, 4 sub-plot treatments and each treatment replicated thrice. The treatments comprised in main plot, i.e. CA practices (tillage and residue management- zero tillage (ZT) + wheat residue (3 tonnes/ha), ZT – bed + wheat residue (3 tonnes/ha), and CT–No residue); and subplot, i.e. K dose and time of application (recommended dose as basal; 60 kg K₂O/ha, half at sowing + half at tasseling, half at sowing + half at silking, and one-third at sowing + one-third at knee high 30 days after sowing + one-third at tasseling). The maize was sown with the help of dibbling. Nitrogen and phosphorus fertilizers were band placed along with sowing by hand and potassium fertilizer was applied manually as per the treatment. The N, P and K were given at the following rates in the form of urea, diammonium phosphate (DAP) and muriate of potash (MoP) respectively. The applied dose of fertilizer was 150, 80 and 60 N, P₂O₅ and K₂O kg/ha. The entire dose of P was applied basal at the time of sowing. Nitrogen was applied in 2 splits, half at the time of sowing and other half at the time of tasseling. Maize variety 'PMH 1' in *kharif* was sown by hand at the seed rate of 20 kg/ha at an inter-row spacing of 70 cm. Growth parameters and yield attributes were recorded at different growth stages of the crop. Plant height and dry-matter production was taken at

harvest stage and leaf-area index, crop-growth rate and relative growth rate were taken at 60 days after sowing (DAS). Protein content in maize was calculated by multiplying nitrogen per cent by the factor 6.25. Soil organic carbon, available N, P and K were determined from the processed samples for each treatment (in triplicate) as per the standard methods (Prasad *et al.*, 2006). The uptake of each nutrient was computed as nutrient uptake = (per cent nutrient content × yield) /100. The data collected on different parameters during the experiment were subjected to appropriate statistical analysis following the procedure described by Gomez and Gomez (1984). Significance of difference between means was tested through F test and the least significant difference (LSD) was worked out where variance ratio (F value) was found significant, critical differences (CD) values at 5% level of probability were computed for making comparison between treatments.

Growth parameters and indices of maize were significantly influenced by zero tillage, residue and potassium management (Table 1). The plant height, dry-matter accumulation (DMA) and leaf-area index (LAI) of maize were higher with zero tillage supplemented with crop residue over the bare soil with conventional tillage (CT). The ZT – bed + residue (3 tonnes/ha) resulted in significantly higher plant height, dry-matter accumulation (DMA), leaf-area index (LAI) and growth indices like crop-growth rate (CGR) and relative growth rate (RGR) of maize than ZT + residue (3 tonnes/ha) and CT–no residue. Compared to the conventional tillage treatment ZT + residue (3 tonnes/ha) performed better but was at par with ZT – bed + residue (3 tonnes/ha). This indicated that zero tillage was as good as conventional tillage in raising the maize crop.

Table 1. Growth parameters and indices of maize as influenced by tillage and potassium management under conservation agriculture

Treatment	Plant height (cm)	Dry-matter accumulation (g/plant)	Leaf-area index	Crop-growth rate (g/m ² /day)	Relative growth rate (g/g/day)
<i>Tillage practice</i>					
ZT + residue (3 t/ha)	223.4	182.8	3.81	2.34	31.4
ZT – bed + residue (3 t/ha)	228.5	189.5	3.67	2.21	27.7
CT – no residue	218.5	178.8	0.03	0.03	0.64
SEm±	2.74	2.26	0.11	0.12	2.53
CD (P=0.05)	7.94	8.81	3.74	0.35	6.88
<i>K application</i>					
K ₁	218.5	181.6	3.72	2.14	28.6
K ₂	228.0	187.5	3.78	2.28	29.
K ₃	223.3	182.5	3.73	2.22	29.8
K ₄	224.0	183.1	3.73	2.25	30.2
SEm±	2.09	1.14	0.01	0.02	0.58
CD (P=0.05)	6.22	3.38	0.04	0.06	NS

K₁, Recommended dose as basal; K₂, half at sowing + half at tasseling; K₃, half at sowing + half at silking; K₄, one-third at sowing + one-third at knee high 30 days after sowing + one-third at tasseling; NS, non-significant

Zero tillage is a principle of CA in which crop residue is retained on the soil surface. Better seed germination and crop establishment might have been the reason for comparatively higher growth of maize in zero tillage-bed with residue application. The better performance in residue-added plots might be attributed to the modified micro-climate under residues, reduced plant water stress during the dry periods due to soil-moisture conservation and reduced soil temperature compared to no-residue plots. Among all the K-management practices in subplot, K₂ (half RD at basal and half at tasseling) have significantly improved all the growth parameters and indices of maize compared to rest of the treatments. It might be owing to synergistic interaction of potassium with other nutrients which resulted in increased nutrient availability for photosynthetic activity in plant at critical growth stages. Potassium is a multifunctional and high mobility element with direct and indirect influence on almost all biochemical and bio-physiological processes. The deficiency of K results in decreased stomatal conductance which caused decreased photosynthesis rate per unit leaf area (Wolf *et al.*, 2006). The different growth parameters of maize were not significantly affected due to interaction of residue and K application treatments except dry-matter accumulation at the time of harvesting.

The yield attributes, viz. cob length, cob girth, cob weight, grain rows/cob, grains/cob and test weight, in maize were significantly influenced by variable tillage, residue and timing of K application practices (Table 2). The maximum values of all the yield-attributing characters were recorded with ZT – bed + residue (3 tonnes/ha). The higher values of yield attributes might be owing to better

germination of maize under zero tillage supplemented by residue retention. Further, residue application maintained good and favourable soil moisture, moderate soil temperature, and improved soil water and nutrient conditions. Saad *et al.* (2015) reported higher value of yield attributes under residue retention. The higher LAI in these treatments might have helped in better photosynthesis and assimilation rate resulting in more dry matter and better growth indices, which ultimately showed higher number of yield attributes. The treatment, K₂ (half RD at basal and half at tasseling) showed significantly higher values of yield attributes in maize. The improvement in yield attributes was owing to the response of applied K in 2 splits at more critical stages, as it is vital to many plant processes including photosynthesis, translocation of photosynthates, protein synthesis and activation of plant enzymes etc. Maize uptakes maximum of the K up to tasseling or for a short time after tasseling which may be the cause of higher values of yield-attributing characters in K₂ (half RD at basal and half at tasseling). Tabatabaai *et al.* (2011) also reported that, application of K increased the number of grains/cob and 1,000-grain weight, grain number/row, grain weight/row in maize.

The application of variable tillage, residue and potassium-management practices resulted significant improvement in grain, stover and protein yield in ZT – bed + residue (3 tonnes/ha) over ZT + residue (3 tonnes/ha) and CT–no residue. The treatment, ZT – bed + residue (3 tonnes/ha) was significantly superior with respect to grain yield, stover yield, and biological yield to ZT + residue (3 tonnes/ha) and CT–no residue. Application of K₂ (half RD at basal and half at tasseling) recorded significantly higher

Table 2. Effect of tillage and K management on yield and yield attributes of maize under conservation agriculture

Treatment	Cob length (cm)	Test weight (g)	Grains/cob	Grain rows/cob	Shelling (%)	Grain yield (t/ha)	Stover yield (t/ha)	Protein yield (kg/ha)	Harvest index (%)
<i>Tillage practice</i>									
ZT + residue (3 t/ha)	15.4	215.4	356.7	13.7	79.34	4.34	8.50	361.7	33.79
ZT – bed + residue (3 t/ha)	16.3	224.4	399.6	15.0	83.23	4.66	9.51	428.4	32.88
CT – no residue	14.3	207.2	334.3	12.3	78.80	4.19	7.56	332.8	35.65
SEm±	0.13	3.36	5.57	0.63	0.82	0.11	0.34	4.68	0.48
CD (P=0.05)	0.51	13.2	21.85	2.50	3.28	0.42	1.35	18.37	1.92
<i>K application</i>									
K ₁	14.8	214.3	362.8	13.7	80.47	4.35	8.43	371.3	34.09
K ₂	15.7	217.8	378.4	13.8	80.35	4.46	8.65	383.7	34.08
K ₃	15.1	215.2	362.2	13.6	80.39	4.35	8.46	366.7	34.03
K ₄	15.6	215.44	350.7	13.5	80.63	4.43	8.55	375.5	34.22
SEm±	0.10	1.01	3.57	0.15	0.54	0.03	0.05	3.45	0.22
CD (P=0.05)	0.30	NS	10.61	NS	NS	0.09	0.16	10.25	NS

K₁, Recommended dose as basal; K₂, half at sowing + half at tasseling; K₃, half at sowing + half at silking; K₄, one-third at sowing + one-third at knee high 30 days after sowing + one-third at tasseling; NS, non-significant

grain yield, stover yield and biological yield than the other treatments in subplots. The harvest index (HI) of maize showed significant difference due to different tillage and crop residue-management practices. Highest HI was obtained in CT–no residue over ZT + residue (3 tonnes/ha) and ZT – bed + residue (3 tonnes/ha). Protein content in maize responded positively owing to the conservation agricultural practices and timing of K application. The highest protein content was recorded with ZT – bed + residue (3 tonnes/ha) over ZT + residue (3 tonnes/ha) and CT–no residue. The treatment, ZT – bed + residue (3 tonnes/ha) was significantly superior in respect of protein content in seed and protein yield. The lowest values were recorded in CT–no residue. Among timing of K application, K₂ (half RD at basal and half at tasseling) recorded significantly higher values than the other treatments. The lowest value was obtained in K₃ (half RD as basal and half at silking). The residues added considerable amounts of N in soil after their decomposition and maintained the soil organic carbon status that resulted in better enzymatic activities in soil and increased the status of N availability in soil which might have resulted in higher nutrient absorption by the crop manifested in terms of higher protein content and protein yield.

The estimation of nutrient content (N, P and K) in grain and stover of maize indicated marked variation in content and uptake of nutrients in grain and stover at harvesting with conservation agricultural practices and timing of K application (Table 3). The ZT – bed + residue (3 tonnes/ha) registered significantly higher N, P and K content in seed and stover followed by ZT + residue (3 tonnes/ha) and CT–no residue. The increased nutrient content in ZT

– bed + residue (3 tonnes/ha) and ZT + residue (3 tonnes/ha) was owing to the beneficial effect of residues. The residues added considerable amounts of nutrients in soil after their decomposition and maintained the soil organic carbon status that resulted in better enzymatic activities in soil and increased the status of nutrient availability in soil which might have resulted in higher nutrient absorption by the crop. Among the timing of K application practices, higher N, P and K content in seed and stover of maize was observed in K₂ (half RD at basal and half at tasseling) in most of the cases with certain exceptions. There was no significant difference in N concentration in grains but it was significant in stover, N uptake by grain, stover and total uptake. Total uptake of N was the lowest in K₁ (RD as basal). Concentration of P was not significantly different in grain and stover with respect to timing of K application. The uptake of P by grain and total uptake was significantly higher in K₂ (half RD at basal and half at tasseling) than other treatments. Potassium concentration was not significantly different in grain with respect to timing of K application. The K concentration in stover and uptake by grain and stover was significantly higher in K₂ (half RD at basal and half at tasseling) than the other treatments. There was significant interaction effect of conservation agricultural practices and timing of potassium application practices on N concentration in stover, total N uptake in stover and total N uptake by both grain and stover, on P uptake by stover and no significant effect on K concentration in grain, stover and uptake of K.

The superior growth parameters, yield attributes, grain and stover yield and N, P and K uptake were obtained in ZT – bed + residue (3 tonnes/ha) over ZT + residue (3

Table 3. Nutrient uptake of maize as influenced by tillage and K management under conservation agriculture

Treatment	N uptake by grain (kg/ha)	N uptake by stover (kg/ha)	Total N uptake (kg/ha)	P uptake by grain (kg/ha)	P uptake by stover (kg/ha)	Total P uptake (kg/ha)	K uptake by grain (kg/ha)	K uptake by stover (kg/ha)	Total K uptake (kg/ha)
<i>Tillage practice</i>									
ZT + residue (3 t/ha)	57.8	36.0	93.9	10.8	10.6	21.4	21.4	138.5	159.9
ZT – bed + residue (3 t/ha)	68.5	50.2	118.7	12.2	14.8	27.0	23.8	157.1	181.95
CT – no residue	53.3	25.4	78.7	9.19	8.8	17.9	19.2	121.4	140.5
SEm±	0.75	0.63	1.17	0.43	0.52	0.84	0.72	3.16	3.25
CD (P=0.05)	2.94	2.48	4.61	1.71	2.06	3.36	2.86	12.6	12.80
<i>Timing of K application</i>									
K ₁	59.4	36.3	95.7	10.7	11.2	21.9	20.8	136.3	157.1
K ₂	61.4	38.6	100.0	11.1	12.0	23.1	21.9	141.5	163.4
K ₃	58.7	37.2	95.9	10.4	10.9	21.3	21.1	137.9	159.1
K ₄	60.08	36.7	96.8	10.7	11.5	22.2	22.0	140.3	162.3
SEm±	0.55	0.51	0.66	0.20	0.28	0.42	0.26	1.13	1.12
CD (P=0.05)	1.64	1.50	1.95	0.60	NS	1.26	0.78	3.36	3.32

K₁, Recommended dose as basal; K₂, half at sowing + half at tasseling; K₃, half at sowing + half at silking; K₄, one-third at sowing + one-third at knee high 30 days after sowing + one-third at tasseling

tonnes/ha) and CT–no residue. Application of K in 2 splits, i.e. half RD at basal and half at tasseling, recorded significantly higher grain yield, stover yield and nutrients uptake than other treatments in subplots, that are at par with 3 splits, i.e. one-third at sowing + one-third at knee high 30 days after sowing + one-third at tasseling.

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