Response of hybrid maize (*Zea mays* L.) to differential placement of NPK doses and K splitting for yield and nutrient uptake

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ABSTRACT : The study was carried out during kharif 2016 and 2017 at GBPUA&T, Pantnagar to investigate the effect of potassium splitting and differential placement of NPK doses on dry matter yield, NPK content and uptake by hybrid maize. The experiment consisting of two K split applications (100% K as basal and 50% as basal + 50 % before earthing up practice) and eight NPK doses (different combinations of NPK at 75 and 100% of recommended dose) was conducted in factorial RBD with three replications. The differential placement was done in equal splits at 5 cm and 10-12 cm depths. The control was farmers' practice (100% NPK dose with100% K as basal at 5 cm depth). The nutrient contents in grain, stover and rachis did not vary significantly due to different nutrient management practices except N content in stover and rachis. Dry grain (3.95 t/ha) and stover (6.17 t/ha) yields and uptake of N (110.6 kg/ha), P (32.3 kg/ha) and K (102.4 kg/ha) were found significantly higher with split application of potassium. Differential placement of 100% dose of NPK, being at par with 100% NP + 75% K and 100% NK + 75% P resulted into significantly higher dry matter yields and total N and K uptake by maize than other treatments. Significantly higher P uptake was also noticed in 100% NPK which was at par with 100% NP+75% K. Farmers' practice was significantly inferior to differential placement of 100% NPK fertilizers under both with and without K split application for yield.

Key words: Fertilizer placement, maize, NPK, split

Maize (*Zea mays* L.) is an important food, feed and fodder crop and also used as raw materials for many industrial products. Now-a-days farmers prefer hybrid maize varieties as they have high production potential. Maize being an exhaustive crop absorbs more nutrients from soil than by most of other cereals (Jat *et al.* 2013). Thus, buffering pressure on the soil reserves must be provided with nutrient application in sufficient quantity and in a manner to cater crop needs. Basal application of K leads to its fixation in soil and availability gets reduced during active growth phases. Application of K at vegetative stage has been proven more beneficial for increasing the efficiency of applied K (Romheld and Kirkby, 2010). So, there is need to split K application to improve its efficiency in maize. In maize earthing is done at knee height stage, thus there is an opportunity to apply K prior to earthing along the crop rows.

To maize, conventionally basal dose of NPK is applied in furrows at 5-6 cm depth. While in the later stage, roots go beyond this zone and may encounter poor availability of nutrients. This concept warrants that there is need to place fertilizers in different depths to improve its availability and efficiency. Placement of fertilizers at different depths, with half in seed furrows may provide good initial start to growing plants and remaining amount applied at 10-12 cm depth will fulfill the plant needs in later growth stages. Banding of fertilizers in the root zone reduces fixation and adsorption of nutrients such as P and K by soil particFles and helps in increasing their availability (Fernández and White, 2012 and McLaughlin *et al.*, 2011). Additionally, fertilizer applied in deep bands which remains relatively moist would further enhance the nutrient solubility and availability to the crop.

Therefore, fertilizer application at different depths and splitting of potassium would reduce the nutrient losses from soil, hence may result in nutrient economy. It is very much essential particularly with availability of new high yield potential hybrids. Present study envisages assessing the effect of K splitting and differential placements of variable NPK doses on grain and stover dry matter yields, nutrients content and their uptake by maize during rainy season.

MATERIALS AND METHODS

The experiment was conducted during *kharif* 2016 and 2017 at the Norman E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, situated at 29˚ N latitude, 79.5˚ E longitude and at an altitude of 243.83 m above mean sea level. The soil of the experimental site was silty clay loam in texture, neutral in reaction (pH 7.2), medium in organic carbon (0.71%), low in available N (234.9 kg/ha) and medium in available P and K (20.7 and 212.4 kg/ha, respectively).

The experiment consisted of two potassium splitting (100% K as basal and 50% K basal + 50 % K at earthing up) and eight combinations of NPK doses at 75 and 100 % recommended levels. Basal dose of fertilizers were applied at two depths (50 % fertilizers in seed furrows at 5 cm depth and 50% in root zone at 10-12 cm depth). Thus total 16 treatment combinations were tested in a factorial randomized block design with three replications. The control was farmers' practice (100% NPK dose with 100% K basal applied in seed furrows at 5 cm depth). As per treatment, half dose of basal fertilizers was applied at 10-12 cm deep in furrows made by sugarcane planter. After application of fertilizers, furrows were back filled with soil and leveled. Then 5 cm deep shallow furrows were opened exactly on the deep furrows so that fertilizers are just below the crop row. The remaining half dose of fertilizers was applied in shallow furrows. As per treatment half dose of K was applied prior to earthing process (30-35 DAS). Prior to K application, urea was applied in order to reduce the fixation of applied K.

The gross plot and net plot size was 6.0 m × 4.8 m and 2.25 m × 4.4 m, respectively. For farmers' practice these were 14.25 m × 4.8 m and 10.5 m × 4.4 m, respectively. The recommended dose of nutrients was 150-60-40 kg N-P_2O_5-K_2O/ha. Maize was sown at spacing of 75 cm × 20 cm in 5 cm deep furrows. Hybrid variety of maize namely 'P3396' was used. The sources of nutrients were NPK mixture (12-32-16), urea, di-ammonium phosphate and muriate of potash. Nitrogen was applied in three equal splits at sowing, knee height and at tasseling stage. Total quantity of phosphorus was given as basal and potassium was applied as per the treatment. In farmers' practice treatment, one third dose of N and entire P and K were applied at sowing in seed furrows as basal and remaining nitrogen in two equal doses at knee height and at tasseling stages. During both the years maize was grown in fixed plots with same layout. Wheat was taken as succeeding crop in *rabi* season with recommended package of practice to complete crop rotation.

After plucking the cobs, the plants were cut just above the soil surface and weighed for each net plot. The cobs from each net plot were shelled and grain and rachis weight was recorded. A representative sample of 100 g each of grain and rachis and 200 g of stover was taken from all plots and kept for drying in a dryer at 65 ± 5^0 C temperature for 72 hrs. The oven dry weight of these samples was recorded. On the basis of oven dry weight grain, stover and rachis yield of respective plots was converted into dry matter yield.

For the chemical analysis dried grain, stover and rachis samples were ground and passed through 0.5 mm sieve. The plant samples were analyzed for NPK contents as per the procedure described by Jackson (1973). Uptake of NPK in different plant parts was calculated by multiplying respective dry matter yields with respective nutrient content. Total nutrient uptake was calculated by adding uptake by grains, stover and rachis. Data recorded on various parameters for both the years were averaged and were analyzed as per the analysis of variance technique for factorial randomized block design described by Gomez and Gomez (1984) at 5% level of significance. To compare farmers' practice with differential fertilizer placement with K split and without K split, 'student t' test was used at 5% level of significance as per the procedures explained by Ragnaswami (2006).

RESULTS AND DISCUSSION

Dry matter yield

Significant improvement in dry matter yield of grain and stover of maize was observed with split application of K during both the years (Table 1). However, rachis yield remained statistically unaffected. Gain in grain and stover dry yield due to K splitting was 5.3 and 5.1 per cent, respectively over 100% basal application. A sizeable amount of basal applied K is likely to be fixed in the inter-layer space of soil colloids as soil of experimental site was rich in Illite minerals. It resulted into reduced availability of this K at the time of peak

Table 1: Effect of K splitting and differential placement of nutrient doses on dry matter yields of maize (mean of 2 years)

Treatments	Dry grain yield (t/ha)	Dry stover yield (t/ha)	Dry rachis yield (t/ha)
Potassium application*			
100% basal	3.75	5.88	1.38
50 % basal + 50% split	3.95	6.18	1.45
SEm ±	0.05	0.07	0.04
CD (p = 0.05)	0.15	0.21	NS
Nutrient doses* (per cent of recommended NPK)			
75-75-75	3.12	5.03	1.22
75-75-100	3.40	5.48	1.29
75-100-75	3.50	5.65	1.30
75-100-100	3.76	5.87	1.39
100-75-75	4.11	6.35	1.49
100-75-100	4.29	6.57	1.53
100-100-75	4.28	6.59	1.51
100-100-100	4.38	6.70	1.60
SEm ±	0.10	0.15	0.08
CD (p = 0.05)	0.30	0.42	0.23
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK with K splitting			
FP	3.96	6.09	1.47
DFP+ K splitting	4.49	6.86	1.59
t- value	8.34	3.01	0.77
Significance	S	S	NS
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK without K splitting			
FP	3.96	6.09	1.47
DFP only	4.28	6.53	1.60
t- value	6.21	1.70	0.98
Significance	S	NS	NS

*treatments were laid out under differential fertilizer placement

demand of crop. More availability of K under split application at active vegetative stage improved plant enzymatic activities and subsequently caused higher yield (Saleem *et al.,* 2011).

Increasing nutrient dose from 75 to 100% of recommended level significantly increased dry yield of grain and stover except rachis. The 100% NPK dose acquired significantly higher dry yield of grain (4.38 t/ha) and stover (6.70 t/ha) but remained at par with all other doses having 100% N along with 75 or 100% P and K. A reduction in NPK dose from 100 to 75% of recommended significantly reduced grain, stover and rachis dry matter yields to a tune of 28.8, 24.9 and 23.7 per cent, respectively. Nitrogen is essential for protein synthesis and photosynthesis and thus influences dry matter yield of plants. Similarly, phosphorus is essential for energy storage and generation, while potassium is required for enzyme activation for various plant processes. More availability of nutrients in recommended dose resulted in higher dry matter yield. Findings of Thakur *et al.* (2009) and Srinivasa *et al.* (2015) also revealed that higher nutrient dose was essential to enhance maize yield.

Differential placement of fertilizers both under 100% K as basal and K split application produced significantly higher dry grain yield as compared to farmer's practice, while stover and rachis dry yields did not vary significantly. The increase in grain yield was 13.4 per cent with K split application and 12.6 per cent without K split application. Fertilizer placements at different depths (seed and root zone) made easy accessibility of nutrients to roots which caused higher nutrient removal and consequently higher yield. Fernández and White (2012) also found significantly higher yield of maize with deep placement of fertilizer.

Nutrient content

Nutrients content in grains, stover and rachis did not vary significantly due to split application of K (Table 2). However, split application of K numerically increased the N, P and K content over entire K application as basal. Recommended NPK dose resulted into higher N, P and K

Table 2: Nutrients content of maize as affected by K splitting and differential placement of nutrient doses (mean of 2 years)

Treatments	N content (%)			P content (%)			K content (%)		
	Grain	Stover	Rachis	Grain	Stover	Rachis	Grain	Stover	Rachis
Potassium application*									
100% basal	1.533	0.715	0.335	0.406	0.211	0.155	0.459	1.245	0.391
50% basal+50% split	1.539	0.722	0.339	0.416	0.217	0.159	0.468	1.264	0.398
SEm ±	0.014	0.004	0.002	0.005	0.002	0.002	0.004	0.007	0.004
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient doses* (per cent of recommended NPK)									
75-75-75	1.484	0.689	0.328	0.394	0.206	0.153	0.454	1.241	0.388
75-75-100	1.500	0.698	0.333	0.396	0.209	0.155	0.460	1.253	0.394
75-100-75	1.516	0.701	0.334	0.400	0.214	0.159	0.457	1.243	0.391
75-100-100	1.529	0.714	0.331	0.416	0.220	0.160	0.464	1.257	0.393
100-75-75	1.551	0.733	0.339	0.411	0.210	0.152	0.460	1.246	0.389
100-75-100	1.566	0.733	0.339	0.416	0.214	0.155	0.473	1.264	0.400
100-100-75	1.565	0.732	0.345	0.423	0.216	0.159	0.467	1.258	0.398
100-100-100	1.577	0.747	0.349	0.435	0.225	0.165	0.476	1.272	0.405
SEm ±	0.028	0.007	0.004	0.010	0.004	0.003	0.009	0.014	0.007
CD (p = 0.05)	NS	0.022	0.011	NS	NS	NS	NS	NS	NS
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK with K splitting									
FP	1.552	0.730	0.344	0.412	0.220	0.161	0.467	1.255	0.398
DFP+ K splitting	1.582	0.755	0.352	0.438	0.228	0.167	0.480	1.277	0.409
t- value	0.636	0.678	0.541	1.489	1.356	1.369	0.736	0.460	0.736
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK without K splitting									
FP	1.552	0.730	0.344	0.412	0.220	0.161	0.467	1.255	0.398
DFP only	1.572	0.739	0.346	0.431	0.223	0.164	0.471	1.267	0.401
t- value	0.307	0.291	0.160	0.592	0.462	0.468	0.333	0.257	0.337
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS

*treatments were laid out under differential fertilizer placement

contents in grains, stover and rachis but did not show statistical superiority over other nutrient combinations except for N content in stover. Maize fertilized with 100% NPK recorded significantly higher N content in stover (0.747%) than others except treatments having 100% N along with either 75 or 100% P and K. Differential fertilizer placements both under with and without K split application recorded higher nutrient content over farmers' practice, however the increase was not significant. The higher nutrient contents under recommended NPK levels were because of higher amount of nutrients applied to maize, which increased their availability to the crop.

Nitrogen uptake

Split application of K brought significant variation in N uptake by grains, stover and total uptake by crop except by rachis (Table 3). As compared to 100% K basal application, split application recorded higher nitrogen uptake by 5.7% in grains, 5.9% in stover and 5.8 % total uptake by crop. Application of 100% recommended NPK being at par with 100% NK+75% P and 100% NP+75% K attained significantly more N uptake in grain, stover, rachis and total uptake by crop (69.1, 50.1, 5.6 and 124.7 kg/ha, respectively). Differential fertilizer placement with K splitting had more N uptake than farmers' practice and was found significantly higher for uptake of N by grains and total N uptake by crop. But differential fertilizer placement without K splitting did not vary significantly with farmers' practice for N uptake by crop however, it attained higher values.

Phosphorus uptake

Splitting of K in two equal doses resulted into significantly higher uptake of P by grains (16.5 kg/ha), stover (13.4 kg/ha) and whole crop (32.3 kg/ha) than whole K basal application (Table 4). An increasing trend in P uptake with nutrient dose was noticed. P uptake was found significantly more in 100% NPK and remained at par with 100% NK+ 75% P and 100% NP+ 75% K for grains (19.1 kg/ha) and stover (15.1 kg/ha) while for total

Table 3: Influence of K splitting and differential placement of nutrient doses on nitrogen uptake by maize (mean of 2 years)

Treatments	N uptake (kg/ha)			
	Grain	Stover	Rachis	Total
Potassium application*				
100% basal	57.7	42.2	4.6	104.5
50 % basal+50% split	61.0	44.7	4.9	110.6
SEm ±	0.9	0.6	0.1	1.2
CD (p=0.05)	2.6	1.7	NS	3.4
Nutrient doses* (per cent of recommended NPK)				
75-75-75	46.2	34.7	4.0	85.0
75-75-100	51.2	38.2	4.3	93.7
75-100-75	52.9	39.6	4.4	96.9
75-100-100	57.5	41.8	4.6	103.9
100-75-75	63.7	46.5	5.0	115.3
100-75-100	67.2	48.3	5.2	120.6
100-100-75	66.9	48.2	5.2	120.4
100-100-100	69.1	50.1	5.6	124.7
SEm ±	1.8	1.2	0.3	2.4
CD (p = 0.05)	5.2	3.4	0.8	6.8
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK with K splitting				
FP	61.5	44.6	5.1	111.1
DFP+ K splitting	70.9	51.9	5.6	128.4
t- value	4.30	1.82	1.47	3.62
Significance	S	NS	NS	S
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK without K splitting				
FP	61.5	44.6	5.1	111.1
DFP only	67.2	48.3	5.6	121.1
t- value	1.71	1.12	0.93	1.56
Significance	NS	NS	NS	NS

*treatments were laid out under differential fertilizer placement

uptake by crop (36.8 kg/ha) it was found at par with only 100% NP+ 75% K. P uptake by rachis (2.6 kg/ha) was also recorded significantly higher in 100% NPK dose but it was found at par with all the treatments in which 100% N was used. Phosphorus uptake by grain, stover and total uptake was also recorded significantly higher under differential fertilizer placement with K split application compared to farmers' practice. Differential fertilizer placement without K split application also caused higher values of P uptake by crop but differences were not significant.

Potassium uptake

K uptake in grains, stover and whole crop was recorded significantly higher under K splitting over the 100% basal K application by 6.9, 6.5 and 6.8 per cent, respectively (Table 5). K uptake by rachis remained statistically at par between K application methods. Increase in nutrient doses led to enhancement in K uptake. The potassium uptake by grains, stover, rachis and by whole crop was noted significantly higher in 100% NPK dose (20.8, 85.2, 6.5 and 112.5 kg/ha, respectively) where it was at par with 100% NK+ 75% P and 100% NP+ 75% K. For rachis it was also at par with 100% N+75% K. Differential fertilizer placement with K split application had significantly more K uptake by grain, stover and total uptake by crop than farmers' practice. K uptake by stover and total uptake by crop under differential fertilizer placement without K split application was also significant as compared to farmers' practice.

The nutrient uptake by crop is a product of nutrient content and dry matter yield. Significantly higher values of grain, rachis and stover yields and higher nutrient contents led to significantly more uptake of nutrients under high nutrient dose treatments. Wiendl and Döwich (2016) also found significantly higher uptake of nutrients

Table 4: P uptake by maize as affected by K splitting and differential placement of nutrient doses (mean of 2 years)

Treatments	P uptake (kg/ha)			
	Grain	Stover	Rachis	Total
Potassium application*				
100% basal	15.3	12.5	2.1	29.9
50 % basal+50% split	16.5	13.4	2.3	32.3
SEm ±	0.3	0.2	0.1	0.4
CD (p = 0.05)	0.8	0.6	NS	1.1
Nutrient doses* (per cent of recommended NPK)				
75-75-75	12.3	10.4	1.9	24.6
75-75-100	13.5	11.4	2.0	26.9
75-100-75	14.0	12.1	2.1	28.2
75-100-100	15.7	12.9	2.2	30.8
100-75-75	16.9	13.4	2.3	32.5
100-75-100	17.8	14.1	2.4	34.3
100-100-75	18.1	14.2	2.4	34.7
100-100-100	19.1	15.1	2.6	36.8
SEm ±	0.6	0.4	0.1	0.8
CD (p=0.05)	1.7	1.1	0.4	2.2
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK with K splitting				
FP	16.3	13.4	2.4	32.1
DFP+ K splitting	19.7	15.6	2.7	37.9
t- value	4.19	3.25	1.1	9.41
Significance	S	S	NS	S
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK without K splitting				
FP	16.3	13.4	2.4	32.1
DFP only	18.5	14.6	2.6	35.7
t- value	1.46	1.57	0.9	2.53
Significance	NS	NS	NS	NS

*treatments were laid out under differential fertilizer placement

Table 5: Effect of K splitting and differential placement of nutrient doses on K uptake by maize (mean of 2 years)

Treatments	K uptake (kg/ha)			
	Grain	Stover	Rachis	Total uptake
Potassium application*				
100% basal	17.3	73.3	5.4	95.9
50 % basal+50% split	18.5	78.1	5.8	102.4
SEm ±	0.3	1.0	0.1	1.1
CD (p=0.05)	0.8	2.8	NS	3.3
Nutrient doses* (per cent of recommended NPK)				
75-75-75	14.1	62.4	4.7	81.3
75-75-100	15.7	68.7	5.1	89.4
75-100-75	16.0	70.3	5.1	91.4
75-100-100	17.4	73.8	5.5	96.7
100-75-75	18.9	79.1	5.8	103.8
100-75-100	20.3	83.1	6.1	109.5
100-100-75	20.0	82.9	6.0	108.9
100-100-100	20.8	85.2	6.5	112.5
SEm ±	0.6	2.0	0.3	2.3
CD (p = 0.05)	1.6	5.7	0.9	6.6
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK with K splitting				
FP	18.5	76.4	5.8	100.7
DFP+ K splitting	21.5	87.7	6.5	115.7
t- value	4.29	3.15	1.4	3.76
Significance	S	S	NS	S
Farmers' practice (FP) vs differential fertilizer placement (DFP) under 100% NPK without K splitting				
FP	18.5	76.4	5.8	100.7
DFP only	20.2	82.7	6.4	109.3
t- value	2.66	3.06	1.5	4.47
Significance	NS	S	NS	S

*treatments were laid out under differential fertilizer placement with split application of nutrients. Significantly higher uptake of N with more amount of nutrients in maize was also reported by Bisht *et al*. (2013). Similarly, higher nutrient accumulation in maize with deep fertilizer placement has also been reported by Borges and Mallarino (2001).

CONCLUSION

Application of K in maize in two equal splits as basal and at earthing up stage was more advantageous than 100% K as basal for nutrient content, uptake and yields. Band placement of basal dose of fertilizers in two soil depths i.e. seeding zone and 5-6 cm below seeding zone should be adopted for improving nutrient availability.

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