Vol. 20(12), pp.465-469, December 2021
DOI: 10.5897/AJB2021.17383
Article Number: 14BAB4368432
ISSN: 1684-5315

http://www.academicjournals.org/AJB

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African Journal of Biotechnology

Full Length Research Paper

Effect of foliar application of nitrogen-phosphorus-potassium fertilizers on nutrient uptake and protein content of maize

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Received 9 July, 2021; Accepted 9 November, 2021

The effect of foliar application of nitrogen-phosphorus-potassium (NPK) fertilizers on nutritional status and yield of maize (*Zea mays* L.) were investigated through a study conducted in a zonal agricultural research station of University of Agricultural Sciences, GKVK Bengaluru (India). The experiment was laid out in randomized complete block design. The treatments consisted of two levels of soil application (75 and 100%) of recommended dose of fertilizer (RDF) and foliar applications of NPK (19:19:19). The fertilizers were applied at 6-leaf, tasselling, knee height and tasseling growth stages. Nutrient uptake, protein content and available soil nutrients at harvest were analyzed. Results indicated that soil application of 100% RDF along with foliar sprays of NPK at knee height and tasselling stages significantly produced the highest levels of N, P and K uptake (306.60, 100.57 and 216.24 kg ha^{-1}, respectively) and maximum protein content (11.5%). Use of this fertilizer treatment also resulted into highest available soil N (273.74 kg ha^{-1}), P (59.45 kg ha^{-1}) and K (204.88 kg ha^{-1}). The combined soil application of 100% RDF and foliar application of NPK at knee height and tasseling stages has potential to increase nutrient supply and protein content of the maize crop.

Key words: Maize, foliar application, NPK, nutrient-uptake, protein content.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in the world and it has the highest global production of all cereals due to its high yield potential (FAOSTAT, 2014). About a half of Africa's population produces maize under subsistence farming and utilizes maize as a staple food and source of carbohydrates (Zeller et al., 2006). Maize is an exhaustive crop with high nutrient demand and its productivity mainly depends upon nutrient management system (Setiyono et al., 2010). Therefore, low soil fertility depletion and inadequate soil fertility

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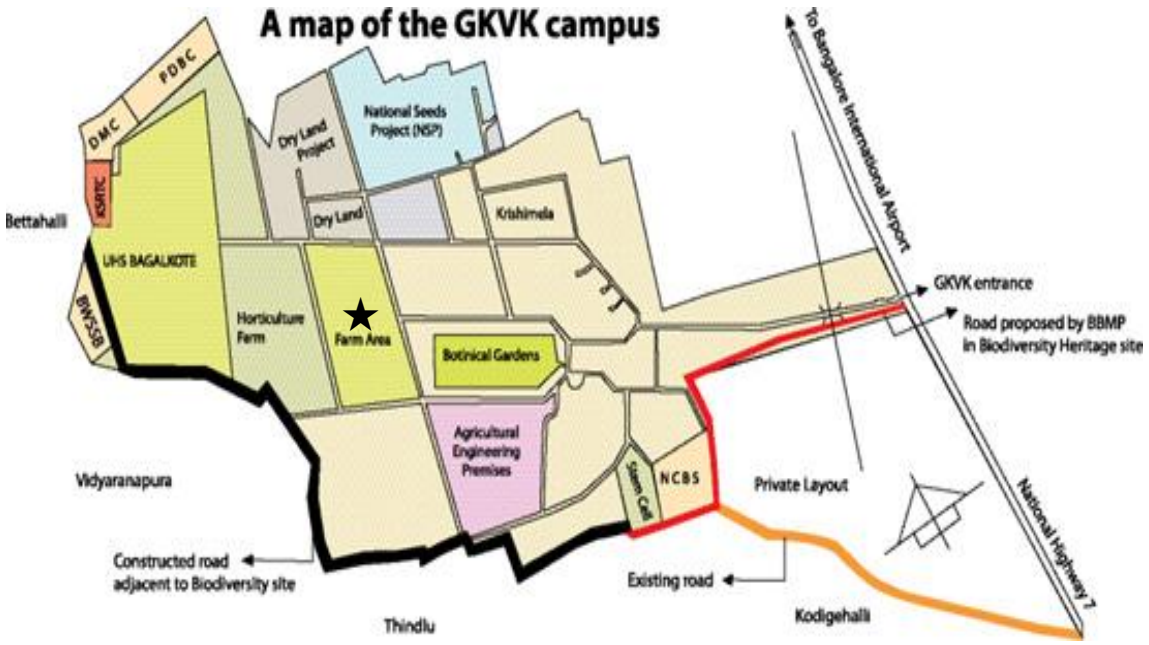

Figure 1. Map of GKVK, University of Agricultural Sciences Bengaluru, Agronomy field unit, Zonal Agriculture Research Station (★) where the experiment was conducted.

management may fail maize yield production (Adediran and Banjoko, 2003).

Nitrogen is the most important and primary essential nutrient for the growth and development of the maize crop (Blumenthal et al., 2008). Thus, nitrogen management in maize production system is one of the main concerns to maximum maize production through NPK fertiliser application (Davis and Westfall, 2011). For many years, NPK fertiliser application has been one of the most practical and effective ways to improve yield and nutritional quality of several crops, including maize (Law-ogbomo and Law-ogbomo, 2009). Increase in yield as a result of application of NPK has been reported in many studies (Jaliya et al., 2008, Jakab-Gabor et al., 2017).

However, limited information is available on the foliar method application complex (NPK) fertilizer at appropriate time of crop growth stage and N use efficiency and maize productivity. Foliar fertilization is commonly used to correct nutritional deficiencies in plants caused by poor supply of nutrients to roots (Ling and Silberbush, 2002). Foliar fertilizer application allows nutrient uptake by leaves considerably faster than roots since the nutrients are readily available in solution form as compared to soil application (Ahmed et al., 2011). Mukund Gowda et al. (2015) demonstrated that foliar application method in pigeon peas resulted into higher uptake of nitrogen, phosphorus and potassium, as compared to soil application method.

Foliar fertilizers have potential to increase agricultural production if applied as recommended and at right time. Application of foliar urea in wheat greatly increased grain protein content (Dampney and Salmon, 1990). In maize, use of foliar NPK fertilizers resulted into increased grain yield as compared to soil application method (Abd EL-Fattah et al., 2012). Yuncai et al. (2008) reported that application of foliar K increased corn (*Z. mays* L.) and soybean yield. Foliar application of boron in faba beans improved uptake and contents of micronutrients; Mn, Zn and Cu in the leaves (Mahmoud et al., 2006). Thus, the objective of this study was to assess the effect of foliar application of NPK fertilizers on nutrients uptake and protein content of maize (*Z. mays* L.).

MATERIALS AND METHODS

Location

Field experiment was conducted in *Kharif* (wet season) 2015 in zonal agricultural research station, GKVK, University of Agricultural Sciences Bengaluru in India (Figure 1). Geographical coordinate was situated between 12° 58^{-1} and 13° 57^{-1} North latitude and 77° 35^{-1} East longitude at an altitude of 930 m above sea level. The precipitation varies from 651.9 to 652.8 mm during growing season. The optimum mean temperature was 23.7°C, and relative humidity was 91.4%. The experimental site was characterized by the soil chemical and physical properties indicated in Table 1.

Experimental design

The experiment employed a completely randomized block design with seven treatments replicated three times. The treatments

Table 1. Soil physical and chemical properties of the experimental site.

Parameter	Value
Soil texture	Coarse sandy loam
Organic carbon (%)	0.65
pH	6.9
EC (dSm^{-1})	0.32
N (Kg ha^{-1})	386.4
P (Kg $ha^{-1)}$	69.3
K (Kg ha^{-1})	291.53

consisted of two levels of soil application of recommended dose of fertilizer (RDF) and foliar applications of water-soluble fertilizers (WSF) were applied as NPK (19:19:19) with 0.5% concentration. Treatment 1 (T_1): 100% RDF + WSF spray at 6-leaf growth stage, T_2: 100 % RDF + WSF spray at tasselling stage, T_3: 100% RDF + WSF spray at knee height and tasselling stages, T_4: 75% RDF + WSF at 6-leaf growth, T_5: 75% RDF + WSF spray at tasselling stage, T_6: 75% RDF + WSF spay at knee height and tasselling stages, and T_7 (control): RDF (150: 75: 40 kg NPK ha^{-1}), and was applied in form of urea, single super phosphate and muriate of potash. Sowing was done on 29 July 2015 using seeds of Hema (NAH-1137) maize variety and other management practices were done as recommended.

Sampling

Five maize plants were sampled with respect to leaves, stem and cob for determination of nutrients uptake and protein content in maize kernel. The kernel samples were air dried and ground using grinder to obtain fine powder. The composite soil sample was taken at 0 to 25 cm depth.

Measurement of mineral nutrient uptake

Mineral concentration in the digested plant material was analyzed to determine nutrient uptake. Nitrogen content was estimated using micro-Kjeldahl procedure (Jackson, 1967) with minor modifications. Phosphorous and potassium contents were determined using vanadomolybdate colour phosphoric reaction and flame photometer method, respectively (Jackson, 1967). The protein content was determined following King-Brink and Sebranek (1993) by multiplying the N content with a convert factor (6.25).

Soil analysis for available NPK

For soil analyses, composite soil samples were air-dried, crushed, sieved and preserved for further analysis of available N, P and K after harvesting. Available soil N was estimated using micro Kjeldahl method following Jackson (1973). Available P in the soil was extracted using sodium hydrogen carbonate and estimated following Olsen's method (Jackson, 1973). Phosphorous was determined by chlorostannous reduced molybdophosphoric blue colour method and the intensity of blue colour was measured at 660 nm using spectrophotometer. The available K content was determined by flame photometer (Model: Systronics FPM-125) according to Jackson (1973).

Statistical analysis

The data were analyzed statistically for test of significance. The level of significance on "F" test was tested at 5%. The data were interpreted using CD values calculated at $p \geq 0.05$ (Gomez and Gomez, 1984) and PROC MIXED procedure based on the mixed linear model of SAS (version 9.4; SAS Institute, Cary, NC). Fisher's protected least significant difference (LSD) test at 0.05 probability level was used to detect differences between treatment means.

RESULTS AND DISCUSSION

Mineral nutrient uptake and protein content

Results in Table 2 show that foliar application of water-soluble fertilizers significantly increased nutrients uptake of maize. Soil application of 100% RDF coupled with foliar spray at 5% concentration of WSF twice at knee height and tasselling stage (T_3) resulted into highest nutrient uptake in both maize kernel and stover. Total nitrogen, phosphorous and potassium up-taken by the plant at this stage were 306.60, 100.57 and 216.24 kg ha^{-1}, respectively. Similarly, this treatment produced the highest protein content in the kernel (11.5%). The lowest total nutrient uptake (nitrogen (235.69 kg ha^{-1}), phosphorous (68.4169 kg ha^{-1}), potassium (134.59 kg ha^{-1}) was observed in 75% RDF + WSF spray at 6-leaf growth stage (T_4). This same treatment (T_4) resulted into the lowest protein content (6.5%) (Table 2). Previous studies showed that foliar application of NPK compensated for insufficient nutrient uptake by the roots in maize (Ling and Silberbush, 2002). Foliar application of K-fertilizer was found to increase absorption of macro elements such as N, P, K, Ca, and Mg and protein content in maize (Suwanarit and Sestapukdee, 1989). Zinc foliar application increases total N uptake (Potarzycki and Grzebisz, 2009). Besides in maize, foliar application of P increases P uptake in wheat (Mosali et al., 2006) while foliar applied iron increases K concentration in soybean seed (Sohrabi et al., 2012).

Available soil nutrients after harvest

Maize sprayed with 100% RDF + WSF at 5%

Table 2. Effect of foliar application of NPK fertilizer on total nutrient uptake and protein content of maize.

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})			Protein content in kernel (%)
	Kernel	Stover	Total	Kernel	Stover	Total	Kernel	Stover	Total	
T_1: 100% RDF + WSF at 6-leaf stage	161.68^{b}	97.37^{bcd}	259.05^{cd}	46.45^{cd}	35.13^{bc}	81.57^{bcd}	38.23^{cd}	137.12^{bc}	175.35^{b}	9.8^{bc}
T_2: 100% RDF + WSF at tasselling stage	182.05^{a}	107.97^{ab}	290.02^{ab}	53.24^{b}	37.92^{b}	91.16^{ab}	46.27^{b}	149.37^{ab}	195.64^{ab}	10.2^{ab}
T_3: 100 % RDF + WSF at knee height and tasselling stage	191.95^{a}	114.66^{a}	306.6^{a}	58.99^{a}	41.58^{a}	100.57^{a}	52.42^{a}	163.82^{a}	216.24^{a}	11.5^{a}
T_4: 75% RDF + WSF at 6-leaf stage	148.02^{b}	87.67^{d}	235.69^{d}	37.56^{e}	30.85^{d}	68.41^{e}	25.98^{e}	108.61^{d}	134.59^{c}	6.5^{e}
T_5: 75% RDF + WSF at tasselling stage	151.18^{b}	90.76^{cd}	241.94^{cd}	43.25^{d}	33.21^{cd}	76.46^{cd}e	33.23^{d}	120.37^{cd}	153.6^{c}	8.1^{de}
T_6: 100 % RDF + WSF at knee height and tasselling stages	164.48^{b}	100.36^{bc}	264.84^{bc}	49.01^{bc}	36.16^{bc}	85.17^{bc}	40.66^{bc}	144.73^{b}	185.39^{b}	10^{ab}
T_7: Control (150: 75: 40 Kg NPK ha^{-1})	150.28^{b}	88.9^{cd}	239.18^{cd}	41.46^{d}e	32.89^{cd}	74.35^{d}e	32.41^{d}	119.55^{cd}	151.96^{c}	8.2^{cd}
S.Em ±	5.38	3.99	8.41	1.73	1.12	3.42	1.92	6.13	6.97	0.6
CD (p= 0.05)	16.57	12.3	25.91	5.33	3.46	10.54	5.91	18.88	21.48	1.7
CV (%)	5.67	7.04	5.55	6.36	5.5	7.18	8.64	7.87	6.97	10.6

Means with by different letters are significantly different at 0.05 probability level.

Table 3. Nutrients status of soil after harvesting of foliar sprayed maize.

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1: 100% RDF + WSF at 6-leaf stage	255.7^{bc}	56.73^{b}	204.58^{a}
T_2: 100% RDF + WSF at 6-leaf stage at tasselling stage	261.22^{ab}	56.53^{b}	203.19^{ab}
T_3: 100 % RDF + WSF at knee height and tasselling	273.74^{a}	59.45^{a}	204.88^{a}
T_4: 75% RDF + WSF at 6-leaf stage	228.09^{e}	48.32^{d}	192.22^{c}
T_5: 75% RDF + WSF at 6-leaf stage at tasselling stage	235.91^{de}	48.55^{d}	194.56^{c}
T_6: 100 % RDF + WSF at knee height and tasselling stages	242.87^{cd}	49.13^{cd}	195.01^{c}
T_7: Control	250.2	51.21 ^{c}	196.7^{bc}
S.Em ±	4.61	0.72	2.49
CD (p= 0.05)	14.2	2.23	7.69
CV (%)	3.2	2.38	2.17

Means with by different letters are significantly different at 0.05 probability level.

concentration spray twice at knee height and tasselling stage (T_3) showed the highest amount of available N (273.74 kg ha^{-1}), P (59.45 kg ha^{-1}) and K (204.88 kg ha^{-1}) in the soil as compared to other treatments (Table 3). While, soil available P_2O_5 was higher with 100% RDF + WSF spray twice at knee height and tasselling stage (59.45 kg ha^{-1}) as compared to other treatments. The soil available K_2O content was significantly higher in100% RDF + WSF spray twice at knee height and tasselling stage (204.88 kg ha^{-1}) or single spray of WSF at 6 leaf growth stage (204.58 kg

ha^{-1}) or at tasselling stage (203.19 kg ha^{-1}) (Table 3). Foliar application of zinc fertilizer in maize showed increased contents of available P and zinc (Potarzycki and Grzebisz, 2009).

Conclusion

Results of the study demonstrate the potential benefits of foliar application of NPK in maize. Application of foliar NPK fertilizers has been using dose of 100% RDF along with foliar sprays of NPK at knee height and tasselling stages can increase plant uptake of macronutrients N, P and K and also result into high protein content in the maize kernel. Furthermore, foliar application of NPK increases available soil NPK thus this method might be suitable in enhancing soil nutrient status. This method of NPK fertilizer application can be adopted in maize cultivation for increasing uptake of N, P and K. However, further research on application techniques can be explored to make foliar application more efficient among maize farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank the government of India for its financial facilities through Indian Council of Culture Relation and Department of Agronomy, University of Agricultural Sciences GKVK, and Bengaluru for providing all possible research facilities for both field experiments and laboratory analyses.

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