IJTA
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National Academy of Agricultural Science (NAAS)
Rating : 3. 03

Effect of Liquid Fertilizers on Yield, Nutrient Uptake and Nutrient Use Efficiency of Rainfed Hybrid Maize (*Zea Mays* L.)

Mavarkar N.S.[1], *Chaithanya*[2] *and Pavan A.S*[3]

Abstract: *The field experiment conducted on "Effect of liquid fertilizers on rainfed hybrid maize (*zea mays *L.) on yield, nutrient uptake and nutrient use efficiency" at the Agricultural and Horticultural Research Station, Bavikere revealed that significantly higher grain yield (83.99 q ha^{-1}) and stover yield (183.38 q ha^{-1}) was recorded with the application of nutrients as per POP + 18:18:18 @ 1.0% + Multi-K @ 1.5%. The available nitrogen was significantly influenced by liquid fertilizers. However, significantly higher available nitrogen (286.2 kg ha^{-1}), available phosphorous (30.4 kg ha^{-1}) and higher available Potassium (191.8 kg ha^{-1}) was recorded in the treatments involving application of nutrients as per POP + 18:18:18 @ 1.0% + Multi-K @ 1.5%. Significantly higher apparent crop nitrogen recovery efficiency (12.32%) and apparent crop potassium recovery efficiency (99.99%) was recorded with the application of nutrients as per POP + 18:18:18 @ 1.0% + Multi-K @ 1.5%. Significantly apparent crop phosphorus recovery efficiency (13.18%) was recorded in the treatment involving POP + 18:18:18 @ 1.0% + Multi-K @ 1.0%. It is concluded that to get maximum productivity, higher nutrient uptake and higher nutrient use efficiency from rainfed hybrid maize in Southern Transition Zone of Karnataka the crop should be fertilized with RDF + FYM @ 7.5 t ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1}(POP) + 18:18:18 @ 1.0% + Multi-K @ 1.5%.*

Keywords: *Liquid fertilizers, Rainfed Hybrid Maize, Nutrient uptake and Nutrient use efficiency.*

INTRODUCTION

In India, maize is cultivated in an area of of 9.4 million ha with a production of 23 million tons with productivity of 2500 kg ha^{-1} (Anon., 2014). In Karnataka, maize is grown on an area of 1.3 million ha with a production of 4.4 million tons and a productivity of 3500 kg ha^{-1} (Anon., 2014). By 2020, the equipment of maize for various sectors will be around 100 million tones.

In Karnataka, maize yield is low due to imbalanced application of fertilizers. The recommendation of fertilizer dose is a challenge to the scientists as it should meet both nutrient demand of the crop as well as sustain the production system (Shankar and Umesh, 2008).

Proper Nutrient management is the most important limiting factor in rainfed maize production. Most often, soils in rainfed areas are not only thirsty but also hungry. It is a well established fact that adequate quantities of nutrients are to be supplied for achieving higher yields. The nutrient management in maize is a complex phenomenon due to its long duration maize plant being a heavy feeder, needs proper supply of plant nutrients for its successive cultivation.

Through water soluble fertilizers, it is easy to supply the precise amount of nutrients required by the plants. The use of water soluble fertilizers in different crops is meager in India, while it is very high in developed countries.

1 Professor (Agronomy), College of Agriculture, UAHS, Shivamogga.
2 Lecturer (Agronomy) and Farm Superintendent, School of Agriculture Science and Forestry (SASF), Rai Technology University, Bengaluru.
3 Assistant Professor (Agronomy), AINRP (T), ZAHRS, Navile, Shivamogga.

Table 1
Effect of liquid fertilizers on yield, nutrient uptake and nutrient use efficiency of rainfed hybrid maize

			Available nutrients in soil (kg ha^{-1})			*Nutrient uptake by crop (kg ha^{-1})*		
Treatments	*Grain yield (q ha^{-1})*	*Stover yield (q ha^{-1})*	*Avail. N*	*Avail. P_2O_5*	*Avail K_2O*	*N*	*P*	*K*
T_1 : RDF	68.00	161.14	265.2	24.2	174.5	175.1	214.3	219.7
T_2 : RDF + FYM @ 7.5 t ha^{-1} +$ZnSO_4$@10 kg ha^{-1} (POP)	70.80	162.39	271.0	26.3	181.1	188.5	224.4	229.4
T_3 : POP + 18:18:18 @ 0.5%	73.90	163.13	270.0	28.6	185.4	198.5	253.1	258.2
T_4 : POP + 18:18:18 @ 1.0%	76.10	167.99	273.6	28.9	186.8	207.6	264.1	271.7
T_5 : POP + 18:18:18 @ 1.5%	78.50	173.67	274.6	29.1	189.6	215.9	275.5	282.6
T_6 : POP + MULTI-K @ 0.5%	73.70	162.16	274.7	27.9	183.2	196.2	228.9	233.4
T_7 : POP + MULTI-K @ 1.0%	75.00	166.30	277.1	28.3	184.1	202.5	237.8	243.0
T_8 : POP + MULTI-K @ 1.5%	77.50	174.16	281.2	29.1	184.5	212.6	246.4	253.3
T_9 : POP + 18:18:18 @ 1.0% + MULTI-K @ 0.5%	80.29	178.03	283.2	28.5	188.2	222.8	286.0	294.0
T_{10} : POP + 18:18:18 @ 1.0% + MULTI-K @ 1.0%	82.75	182.67	284.7	29.3	191.1	233.5	295.3	303.6
T_{11} : POP + 18:18:18 @ 1.0% + MULTI-K @ 1.5%	83.99	183.38	286.2	30.4	191.8	240.2	299.4	307.8
S. Em. ±	1.03	0.52	0.83	0.91	2.73	3.64	2.49	7.54
C.D. at 5%	2.99	1.53	2.47	2.73	8.13	10.92	7.35	22.24

Foliar feeding with plant nutrients gives quick benefits and economizes nutrient element as compared to soil application (Verma, 1973). Foliar feeding is often effective when roots are unable to absorb sufficient nutrients from the soil due to high degree of fixation, losses from leaching, low soil temperature and lack of soil moisture. Foliar application of nutrients for increasing and exploiting genetic potential of the crop is considered as an efficient and economic method of supplementing the nutrient requirement. Application of inorganic spray will also enhance the nutrient availability and in turn increase the productivity. Nutrients play a pivotal role in increasing yield. Foliar application of major and minor nutrients like NPK shall be more effective than soil application and also avoiding the depletion of these nutrients in leaves, thereby resulting in an increased photosynthetic rate, better translocation of these nutrients from the leaves to the developing grains. (Manomani and Srimathi, 2009). Keeping these points in view, the present experiment entitled "Effect of liquid fertilizers on rainfed hybrid maize (*Zea mays* L.) in Southern Transition Zone of Karnataka." was conducted at Agriculture and Horticultural Research Station, Bavikere.

MATERIALS AND METHODS

A field experiment was conducted at the Agricultural and Horticultural Research Station, Bavikere in Completely Randomized Block Design. The soil was red clay loam, slight acidic pH (5.6), Available nitrogen (268.6 kg ha^{-1}), phosphorus (23.6 kg ha^{-1}) and potassium were medium (154.5 kg ha^{-1}). The experiment consisting of eleven treatment combinations T_1: RDF, T_2: RDF + FYM @ 7.5 t ha^{-1} + $ZnSO_4$@10 kg ha^{-1} (POP), T_3: POP + 18:18:18 @ 0.5%, T_4: POP + 18:18:18 @ 1.0%, T_5: POP + 18:18:18 @ 1.5%, T_6: POP + MULTI-K @ 0.5%, T_7: POP + MULTI-K @ 1.0%, T_8: POP + MULTI-K @ 1.5%, T_9: POP + 18:18:18 @ 1.0% +MULTI-K @ 0.5%, T_{10}:POP + 18:18:18 @ 1.0% +MULTI-K @ 1.0% and T_{11}:POP + 18:18:18 @ 1.0% +MULTI-K @ 1.5%.

The treatments were replicated three times in a Randomized Block Design (RBD). The crop was sown at 60 × 30 cm spacing in 24.3 m^2 plot (5.4 m × 4.5 m) in third week of August and harvested in fourth week of December. The fertilizer sources used were urea for N (46 per cent N), Di Ammonium Phosphate for P (18:46:0 per cent water soluble N and P_2O_5), muriate of potash for K (60 per cent of K_2O) and zinc sulphate for Zn (22 per cent Zn).

Table 2
Effect of liquid fertilizers on Apparent crop recovery efficiency and Agronomic use efficiency of rainfed hybrid maize

Treatments	*Apparent crop recovery efficiency (%)*			*Agronomic use efficiency (%)*		
	N	*P*	*K*	*N*	*P*	*K*
T_1 : RDF	5.48	6.94	26.78	–2.80	–5.60	–9.33
T_2 : RDF+FYM @ 7.5 t ha^{-1} +$ZnSO_4$@10 kg ha^{-1}(POP)	0.00	0.00	0.00	0.00	0.00	0.00
T_3 : POP + 18:18:18 @ 0.5%	1.47	2.26	6.20	2.25	4.73	4.56
T_4 : POP + 18:18:18 @ 1.0%	3.12	1.58	17.71	3.83	8.02	7.73
T_5 : POP + 18:18:18 @ 1.5%	5.03	5.69	28.18	5.53	11.56	11.14
T_6 : POP + MULTI-K @ 0.5%	1.12	:0.05	37.75	0.07	0.15	0.15
T_7 : POP + MULTI-K @ 1.0%	3.78	3.50	53.40	3.05	6.20	6.13
T_8 : POP + MULTI-K @ 1.5%	6.51	5.61	72.10	4.87	9.69	9.72
T_9 : POP + 18:18:18 @ 1.0% +MULTI-K @ 0.5%	9.13	9.57	86.01	6.87	14.18	13.85
T_{10} : POP + 18:18:18 @ 1.0% +MULTI-K @ 1.0%	12.07	13.32	97.31	8.63	17.37	17.19
T_{11} : POP + 18:18:18 @ 1.0% +MULTI-K @ 1.5%	12.32	13.18	99.99	9.48	18.64	18.69
S. Em. ±	1.54	0.56	2.45	0.19	0.86	0.46
C.D. at 5%	4.46	1.68	7.10	0.55	2.49	1.33

Growth and yield attributes were recorded as per standard procedures. The nutrient use (kg grain/ kg nutrient) was calculated by dividing the grain yield with total nutrients. The nutrient content and uptake by maize were analyzed through prescribed laboratory procedures. The post harvest soil samples were collected from 0-20 cm depth for analyzing available nutrient status.

RESULTS AND DISCUSSION

The maize yield, available nutrients after crop harvest, nutrient uptake by maize crop, different input use efficiency are presented in Table 1.

The grain yield was significantly influenced by liquid fertilizers. Significantly higher grain yield (83.99 q ha^{-1}) was recorded with the application of nutrients as per POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP +18:18:18 @ 1.0% + Multi-K @ 1.0% (82.75 q ha^{-1}).

The stover yield was also significantly influenced by liquid fertilizers. Significantly higher Stover yield (183.38 q ha^{-1}) was recorded with the application of POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% (182.97 q ha^{-1}), while significantly lower stover yield (161.14 q ha^{-1}) was recorded with the application of RDF alone.

The higher grain and stover yield of rainfed maize was mainly due to better translocation of photosynthates from source to sink and higher growth attributing characters like higher number of green leaves, leaf area and dry matter production and its accumulation into different parts of plant and yield attributing characters like grain weight per cob, number of seeds per cob, number of rows per cob, test weight, cob length and cob girth. These results are in accordance with those obtained by Veeresh (2010) and Ravikumar (2008).

The available nitrogen (kg ha^{-1}) significantly influenced by liquid fertilizers. Significantly higher available nitrogen (286.2 kg ha^{-1}) was recorded in the treatments involving POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% (284.7 kg ha^{-1}) and POP +18:18:18 @ 1.0% + Multi-K @ (0.5%) (283.2 kg ha^{-1}). While, significantly lower available nitrogen (265.2 kg ha^{-1}) was recorded with the application of RDF alone as compared to other treatments.

The available phosphorous significantly influenced by liquid fertilizers. Significantly higher available phosphorous (30.4 kg ha^{-1}) was recorded in POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% (29.3 kg ha^{-1}) and POP +18:18:18 @ 1.0% + Multi-K @ (0.5%) (28.5 kg ha^{-1}), POP + Multi-K @ 1.5% (29.1 kg ha^{-1}), POP + Multi-K @ 1.0% (28.3 kg ha^{-1}), POP + Multi-K @ 0.5% (27.9 kg ha^{-1}), POP +18:18:18 @ 1.5% (29.1 kg ha^{-1}), POP +18:18:18 @ 1.0% (28.9 kg ha^{-1}) and POP +18:18:18 @ 0.5% (28.6 kg ha^{-1}) compared to application of RDF alone and package of practice.

The available potassium significantly influenced by liquid fertilizers. Significantly higher available Potassium (191.8 kg ha^{-1}) was recorded in POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ (0.5%) (188.2 kg ha^{-1}), POP + Multi-K @ 1.5% (184.5 kg ha^{-1}), POP + Multi-K @ 1.0% (184.1 kg ha^{-1}), POP +18:18:18 @ 1.5% (189.6 kg ha^{-1}), POP +18:18:18 @ 1.0% (186.8 kg ha^{-1}) and POP +18:18:18 @ 0.5% (185.4 kg ha^{-1}) compared to application of RDF alone and package of practice. While, significantly lower available potassium (174.5 kg ha^{-1}) was recorded in RDF compared to other treatments.

The nitrogen uptake (kg ha^{-1}) was also significantly influenced by liquid fertilizers. Significantly higher nitrogen uptake (240.2 kg ha^{-1}) was recorded in POP +18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% (233.5 kg ha^{-1}) as compared to other treatments. However, significantly lower available phosphorous (175.1 kg ha^{-1}) was recorded in RDF when compared to POP (188.5 kg ha^{-1}).

The phosphorus uptake (kg ha^{-1}) was significantly influenced by liquid fertilizers. Significantly higher phosphorus uptake (299.4 kg ha^{-1}) was recorded in POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP +18:18:18 @ 1.0% + Multi-K @ 1.0% (295.3 kg ha^{-1}) compared to other treatments. While, significantly lower available phosphorous (214.3 kg ha^{-1}) was recorded with the application of RDF alone when compared to other treatments.

The potassium uptake (kg ha^{-1}) was significantly influenced by liquid fertilizers. However, significantly higher potassium uptake (307.8 kg ha^{-1}) was recorded in POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% (303.6 kg ha^{-1}) and POP + 18:18:18 @ 1.0% + Multi-K @ (0.5%) (294.0 kg ha^{-1}) compared to rest of the treatments. While, significantly lower Available Potassium (196.82 kg ha^{-1}) was recorded with the application of RDF alone when compared to other treatments.

Increase in uptake of nitrogen could be due to higher grain and stover production in that treatment. Higher uptake of N was in conformity with the findings of Hebbar *et al.*, (2004). They revealed that the root growth and NPK uptake by tomato crop was increased by fertigation with water soluble fertilizers over fertigation with normal fertilizers. The higher grain and stover yield in water soluble fertilizer treatments has resulted in higher uptake of phosphorus. In addition, higher phosphorus uptake by the crop is attributed to higher solubility, even distribution of nutrients throughout root zone and higher efficiency of soluble fertilizers. Similar types of observations were made by Shaymaa *et al*. (2009). Higher potassium uptake could be due to higher grain and stover yield which in turn is due to higher efficiency of water soluble fertilizers. Similar results were found with Raina *et al*., (2011) where they concluded that, fertigation with 100 per cent RDF through WSF registered significantly higher leaf NPK content compared to fertigation with commercial fertilizers. This may be attributed to the higher fertilizer use efficiency.

The apparent crop nitrogen recovery efficiency (%) was significantly influenced by liquid fertilizers. Significantly higher apparent crop nitrogen recovery efficiency (12.32%) was recorded in POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% (12.07%) While, significantly lower apparent crop nitrogen recovery efficiency (–5.48%) was recorded in RDF when compared to other treatments.

The nitrogen use efficiency gradually decreases with increase in the application rates of nitrogen. These results are in conformity with the findings of Anitta Fanish and Muthukrishnan (2011) who reported that the efficiency of N is found to decrease with increase in the doses of N. The lower efficiency of N fertilizer at higher N application could be due to higher N losses associated with larger top dressings.

The apparent crop phosphorus recovery efficiency (%) was significantly influenced by liquid fertilizers. Significantly higher apparent crop phosphorus recovery efficiency (13.18%) was recorded in the treatment involving POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% (13.18%). While, significantly lower apparent crop phosphorus recovery efficiency (–6.94%) was recorded in RDF alone when compare to other treatments.

The increase in uptake of phosphorus was noticed when application of phosphorus was in smaller quantity which might have caused in higher efficiency. These results are in conformity with the result of Raina *et al*. (2011).

The apparent crop potassium recovery efficiency (%) was significantly influenced by liquid fertilizers. Significantly higher apparent crop potassium recovery efficiency (99.99%) was recorded in POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% which was on par with POP + 18:18:18 @ 1.0% + Multi-K @ 1.0% (97.31%). While, significantly lower apparent crop potassium recovery efficiency (–26.78%) was recorded in RDF when compare to other treatments.

Efficiency recorded was higher due to higher biomass production which has resulted in higher uptake of K by maize thus leads to higher K efficiency. These results are in conformity with Raina *et al*. (2011).

The agronomic use efficiency of nitrogen (%) was did not differ significantly due to foliar fertilizer application. However, numerically higher agronomic use efficiency of nitrogen (%) was recorded in POP + 18:18:18 @ 1.0% + Multi-K @ 1.5% (9.48%) and numerically lower agronomic use efficiency of nitrogen (%) was recorded in RDF (-2.80%) when compared to other treatments. The agronomic use efficiency of phosphorus (%) was did not differ significantly due to foliar fertilizer application. However, numerically higher agronomic use efficiency of phosphorus (%) was recorded in POP +18:18:18 @ 1.0% + Multi-K @ 1.5% (18.64%). Numerically lower agronomic use efficiency of phosphorus (%) was recorded in RDF (–5.60%) when compared to other treatments. The agronomic use efficiency of potassium (%) was did not differ significantly due to foliar fertilizer application. However, numerically higher agronomic use efficiency of potassium (%) was recorded in POP +18:18:18 @ 1.0% + Multi-K @ 1.5% (18.69%) and numerically lower agronomic use efficiency of potassium (%) were recorded in RDF (-9.33%). due to the higher grain yield thus leads to higher agronomic use efficiency. The uptake of nutrients was more with water soluble fertilizers because of their complete solubility, availability and efficiency compared to normal fertilizers. These results corroborate with earlier findings of Veeranna *et al*., (2001).

CONCLUSION

It can be concluded that to get maximum productivity, higher nutrient uptake and higher nutrient use efficiency from rainfed hybrid maize in Southern Transition Zone of Karnataka the crop should be fertilized with RDF + FYM @ 7.5 t ha^{-1} + $ZnSO_4$ @ 10 kg ha^{-1} (POP) + 18:18:18 @ 1.0% + Multi-K @ 1.5%.

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