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Research Article

Influence of different approaches and forms of fertilizer application on yield and nutrient uptake of hybrid maize

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ABSTRACT

Field experiments were conducted during Kharif 2016-18 at ZARS, UAS, Bengaluru to study the influence of different approaches and forms of fertilizers on maize yield and nutrient use efficiency in Kandic Paleustalf. The results revealed that 26.82% increase in maize kernel yield was recorded in 100% of STCR (Soil Test Crop Response) dose applied through soluble fertilizers (82.66 qha^{-1}) compared to 100% RDF applied through conventional fertilizer (65.18 qha^{-1}). Uptake of nitrogen, phosphorus, and potassium by maize kernel and stover was highest in 100 percent of STCR dose applied through soluble fertilizer than 100% RDF and LMH approach. The highest apparent recovery of nitrogen, phosphorus, and potassium was recorded in 50% of the STCR dose applied through soluble fertilizers. However, the highest value-cost ratio of 7.08 was noticed in the treatment where 100% conventional fertilizers were applied through the LMH approach. The lower VCR in soluble fertilizers applied plots was mainly due to the very high cost of these fertilizers and no subsidy was given to these fertilizers as compared to conventional fertilizers. Application of 50% STCR dose through soluble fertilizer help to save 50% fertilizer nutrients and achieve yield levels higher than the 100% of conventional fertilizers applied as per RDF.

Keywords- *Maize, Soil Test Crop Response, Water Soluble Fertilizers, LMH approach, and Yield.*

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INTRODUCTION

Maize (*Zea mays* L.) is the world's third most important cereal crop, after wheat and rice. In India, it ranks fourth after rice, wheat, and sorghum. Since maize is an exhaustive crop, the nutrient requirement cannot be met only through native nutrient reserves; hence, additional nutrients can be met by fertilizer application [1] In Karnataka, maize yields are low due to the imbalanced application of fertilizers. The recommendation of a proper fertilizer dose is a challenge to scientists, as it should meet both the nutrient demand of the crop and sustain the production system. Fertilizers should be applied in a form that becomes available in synchrony with crop demand for maximum utilization of nutrients from fertilizers [2]. There are several approaches used for fertilizer recommendation for better crop yield and economic production, *viz.,* general recommendations, soil test ratings, fertilizer adjustments (LMH approach), DRIS (Diagnosis Recommendation Integrated System), fertilizer recommendation for targeted yields and fertilizer recommendation through site-specific nutrient management (SSNM). Considering the soil and crop constraints, fertilizers should be applied in synchrony with crop demand in smaller quantities during the growing season. In the present-day context, agriculture is challenged to manage water and nutrients such that production benefits are maximized while adverse environmental effects are minimized. The right combination of water and nutrients is a prerequisite for higher yields and good-quality production. The method of fertilizer application is also important in improving the efficiency of nutrients. Water-soluble fertilizers (WSF) can be defined as the different grades of NPK fertilizers that are completely soluble in water. The growth of micro irrigation systems has helped in the use of 100% water-soluble fertilizers in agriculture. Through water-soluble fertilizers, it is easy to supply the precise amount of nutrients required by plants without any wastage. The use of water-soluble fertilizers in different crops is meager in India, while it is very high in developed countries. In India, these are mainly applied as foliar sprays or through drip fustigation systems.

Drip irrigation systems can easily be used for fustigation, through which crop nutrient requirements can be met accurately [3]. Because of the way the water is applied in a drip system, traditional surface applications of timed-release fertilizer are sometimes ineffective, so drip systems often mix liquid fertilizer with irrigation water**.** So far, the most important use of foliar application has been for micronutrients. The greater difficulty in supplying adequate amounts of N, P, and K through foliar spray lies in its application without severely affecting the crop, such as by burning the leaves. Hence, these water-soluble fertilizers can be used through fustigation. However, in some places, only water-soluble fertilizers are used for direct application to the soil, similar to normal fertilizer application. Drip irrigation is an effective way to supply water to crop plants [4], and usually fertigation improves fertilizer use efficiency by the plants, affecting crop yields [4][5]. Deficiency of N, P, and K is a major production constraint in sandy soils, which have inherent constraints like P fixation, rapid hydraulic conductivity, a faster infiltration rate, leaching of basic cations, and low CEC. Thus, the cultivated crop in this soil requires a large quantity of nutrients to support its growth and yield. So far there was no research efforts have been made to study the use of water-soluble fertilizer with the STCR targeted yield approach. In this context, the present research work was undertaken to study the influence of different approaches and forms of fertilizer application on yield and nutrient uptake of hybrid maize under *Kandic Paleustalf,* a red sandy loam-textured soil.

MATERIALS AND METHODS

Experimental location

On *Alfisols*, field tests were carried out at the Gandhi Krishi Vigyan Kendra, University of Agricultural Sciences, Zonal Agricultural Research Station in Bangalore. The field is located at 13° 04' 55.2" N latitude, 77° 34' 10.0" E longitude, and 930 meters above mean sea level in Karnataka's Eastern Dry Zone. The subtropical humid climate of this area features frigid winters and dry summers. With a mean of 915.8 mm, the annual rainfall ranged from 528 mm to 1374.4 mm. The soil is from the Vijaypura series and has the taxonomical expression *Typic Kandic pale stalks*. It also has a hyperthermic soil temperature. The experimental field's topsoil (0–20 cm depth) has a well-drained sandy clay loam texture, a pH of 6.12, and electrical conductivity.

Experimental Details

A field experiment was conducted with Hybrid Maize (variety: Hema) during Kharif 2016-17 and 2017-18 to access the performance of developed STCR-targeted yield equations in the main experiment with different nutrient management practices in terms of yield attributes and economics(Table 2). The treatment details include T_1: Absolute control, T_2: 100% RDF through conventional fertilizers, T_3: 100% RDF through soluble fertilizers, T_4: 50% of RDF through soluble fertilizers, T_5: 100% of LMH dose through conventional fertilizers, T_6: 100% LMH dose through soluble fertilizers, T_7: 50% of LMH dose through soluble fertilizers, T_8: 100% of STCR dose through conventional fertilizers, T_9: 100 % of STCR dose through soluble fertilizers, T_{10}: 50% of STCR dose through soluble fertilizers with three replications. For all the treatments except control, 10-ton FYM and 10 kg $ZnSO_4$ per hectare were applied. With respect to NPK, different forms of fertilizers and doses were applied as per the treatments. The conventional fertilizers (normal fertilizers) used in the experiment were urea, single super phosphate, and muriate of potash, whereas, 12:61:0, 28:28:00, 00:00:50 grades of NPK and calcium nitrate (15.5 % of N) were used as water soluble fertilizers. The amounts of fertilizers applied in each treatment are given in Table 1.

Three different approaches of nutrient recommendations were adopted in the present study namely, general recommendation or recommended dose of fertilizer (RDF), LMH (Low, medium & high) approach, and STCR targeted yield approach. The number of fertilizers applied through the STCR targeted yield approach was based on the following STCR equation developed at ZARS, Mandya.

FN = 3.84 T - 0.42 SN. ($KMnO_4$ – N)

FP_2O_5 = 1.57 T – 1.18 SP_2O_5. (Bray's P_2O_5)

FK_2O = 1.15 T – 0.11 SK_2O (Am. Acetate K_2O)

[6]

Where,

T = Targeted yield (q ha^{-1}) i.e. 90 q ha^{-1}, FN = Nitrogen supplied through fertilizer (kg ha^{-1}), FP_2O_5 = Phosphorus supplied through fertilizer (kg ha^{-1}), FK_2O = Potassium supplied through fertilizer (kg ha^{-1}), SN, SP_2O_5 and SK_2O are initial available N, P_2O_5 and K_2O kg ha^{-1} respectively.

Prior to sowing, a soil sample was taken, the available N, P2O5, and K2O were assessed, and then nutrients were administered using the STCR and LMH (low-medium-high) techniques to meet particular yield targets. The crop was raised using conventional agronomic techniques, and it was harvested when it reached maturity and yield from the net plot and was expressed in q ha^{-1}.

Table 1. Initial status of soil nutrients and quantity of N, P_2O_5 and K_2O nutrients applied through different forms of fertilizers

Treatments	Initial soil test values (kg ha^{-1})			Quantity of nutrients added (N: P_2O_5: K_2O) kg ha^{-1}		
	Avail. N	Avail. P_2O_5	Avail. K_2O	N	P_2O_5	K
T_1: Control	169.63	152.93	124.80	-	-	-
T_2 : 100 % RDF through CF	214.93	222.63	120.53	150.00	75.00	40.00
T_3 : 100 % RDF through SF	213.21	166.42	154.80	150.00	75.00	40.00
T_4 : 50 % RDF through SF	204.90	192.51	120.80	75.01	37.50	20.00
T_5 : 100 % LMH dose through CF	216.34	104.88	121.60	170.00	65.00	40.00
T_6 : 100 % LMH dose through SF	213.31	231.24	144.00	170.00	65.00	40.00
T_7 : 50 % LMH dose through SF	206.08	173.00	112.80	85.00	32.50	20.00
T_8 : 100 % STCR dose through CF	218.23	156.89	128.00	251.04	49.35	86.67
T_9 : 100 % STCR dose through SF	224.42	158.32	119.20	251.04	49.35	86.50
T_{10} : 50% STCR dose through SF	209.06	177.81	115.87	125.50	24.68	43.25

SF= Soluble fertilizers, CF= Conventional fertilizers

Table 2. Kernal and stover yield (q ha^{-1}) of maize as influenced by different forms of fertilizers and approaches of nutrient recommendations

Table 2. Kernal and stover yield (q ha^{-1}) of maize as influenced by different forms of fertilizers and approaches of nutrient recommendations

Treatments	Kernal yield (q ha^{-1})		Pooled	Straw yield (q ha^{-1})		Pooled
	2012	2013		2012	2013	
T_1: Control	45.25	24.23	**34.74**	64.72	40.12	**52.42**
T_2 : 100 % RDF through CF	73.72	56.64	**65.18**	81.09	63.93	**72.51**
T_3 : 100 % RDF through SF	87.96	66.56	**77.26**	93.15	76.72	**84.93**
T_4 : 50 % RDF through SF	64.28	49.61	**56.94**	68.86	54.01	**61.44**
T_5 : 100 % LMH dose through CF	79.13	66.19	**72.66**	87.04	75.31	**81.18**
T_6 : 100 % LMH dose through SF	92.42	71.81	**82.12**	100.42	80.69	**90.55**
T_7 : 50 % LMH dose through SF	83.53	58.37	**70.95**	89.13	55.56	**72.34**
T_8 : 100 % STCR dose through CF	81.12	66.25	**73.68**	89.23	75.40	**82.31**
T_9 : 100 % STCR dose through SF	94.74	70.58	**82.66**	104.22	81.57	**92.89**
T_{10} : 50% STCR dose through SF	84.56	60.52	**72.54**	91.56	73.85	**82.71**
SEm±	**3.37**	**2.66**	**3.03**	**3.66**	**7.42**	**5.85**
CD (5%)	**10.02**	**7.89**	**10.87**	**10.87**	**22.05**	**16.78**

When the experimental plots were harvested, soil samples (0–20 cm) were taken, processed, and subjected to an examination for available nitrogen (using the alkaline potassium permanganate method), available phosphorus (using Bray's method), and available potassium (neutral normal ammonium acetate extraction). The total NPK content of kernel and stover samples from each treatment was determined using the semi-micro Kjeldahl method by Gherhart instrument [7], the Vanado-molybdate yellow method utilizing spectrophotometry for phosphorus, and the flame photometry for potassium [8].Nutrient uptake, apparent recovery efficiency (ARE), agronomic nutrient use efficiency (ANUE), response yardstick (RYS), and value cost ratio (VCR) were calculated by using the following formulae.

(a) Total nutrient uptake by plant (kg ha^{-1}) = Uptake by plant (kg ha^{-1}) + Uptake by fruit (kg ha^{-1})

$$\text{ARE (kg kg-1)}=\frac{[\text{Nutrient uptake in treated plot}(\text{kg ha}^{-1}) - \text{Nutrient uptake in controle plot } (\text{kg ha}^{-1})]}{\text{Fertilizer nutrient applied}(\text{kg ha}^{-1})}\times 100$$

$$\text{ANUE}(\text{kg kg}^{-1}) = \frac{\text{Grain yield in treated plot } (\text{kg ha}^{-1}) - \text{Kernal yield in control plot } (\text{kg ha}^{-1})}{\text{Fertilizer nutrient applied } (\text{kg ha}^{-1})}$$

$$\text{RYS } (\text{kg kg}^{-1}) = \frac{\text{Yield response } (\text{kg ha}^{-1})}{\text{Total fertilizer applied } (\text{kg ha}^{-1})}$$

$$\text{VCR} = \frac{\{\text{Yield in treated plot } (\text{q ha}^{-1}) - \text{Yield in control plot } (\text{q ha}^{-1})\}\text{ x cost of q}^{-1}\text{kernal}}{\text{Cost of fertilizers and FYM applied to treated plot}}$$

Statistical Analysis

Statistics were used for the information gathered on yield, nutrient uptake, and nutrient availability. P = 0.05 was selected as the level of significance for the "F" and "t" tests. When the 'F' test revealed a significant result, critical difference (CD) values were determined for P = 0.05.

RESULTS AND DISCUSSION

Kernal and Stover yield

The analysis of two years' worth of combined data showed that, regardless of the methods used, treatments that applied soluble fertilizer had much greater kernel and stover yields than those that applied traditional fertilizer. In comparison to all other treatments, T_9, which administered 100% of the STCR dosage using soluble fertilizers, had the highest kernel and stover yields (82.66 and 92.89 q ha^{-1}, respectively) (Table 2). The availability of adequate amounts of nutrients, which were equally distributed in the root zone due to improved solubility of soluble fertilizers, may have contributed to higher nutrient absorption and higher yield in these treatments. When 50% of the STCR dosage was administered using soluble fertilizers (T_{10}) compared to 100% of the RDF applied (T_2) using conventional fertilizers (65.18 and 72.50 q ha^{-1}, respectively), the kernel and stover yields were significantly greater (72.54 and 82.71 q ha^{-1}, respectively). This demonstrates the superiority of the STCR technique for prescribing fertilizer over the package of practices and soil test value approaches to fertilizer application. Both the onion crop [9],[10] and the carrot crop [11] have revealed a similar tendency.

Due to their higher solubility and even distribution, which aid in their direct availability to crops in the root zone and efficient utilization by the crop, water-soluble fertilizers applied at lower rates were more effective in producing higher yields [13]; [14]. Additionally, soluble fertilizers reduce nutrient losses and improve nutrient usage efficiency. While maintaining the same yield, the use of WSF may allow for a 20–30% reduction in fertilizer that is needed. The crops might be able to utilize the greatest amount of nutrients by applying a conveniently available type of fertilizer, namely by lowering the number of nutrients at application, minimizing leaching and volatilisation

losses, and improving nutrient usage efficiency.
This demonstrated that soluble fertilizer dosages produced a greater yield when used positively. The application of soluble fertilizer improves overall development by increasing nutrient mobility, and absorption, and lowering pollution of surface and groundwater. The fact that soluble fertilizers' direct availability and efficiency are balanced out by the application of larger dosages of nutrients may also be a contributing factor in the increase in kernel production at lower doses of nutrients. These findings are consistent with those of [15] and [16].The data also makes it abundantly evident that large yields were reported whenever greater nitrogen dosages were supplied using soluble fertilizer. [17] reported similar findings.

Uptake of nutrients by maize crop

The maximum nitrogen uptake by maize kernal and stover (140.51 kg N ha^{-1}) occurred when a 100% STCR dosage was administered using soluble fertilizer (T9). As a result, the total nitrogen intake in this treatment was also greater (193.88 kg N ha^{-1}) than it was when RDF and LMH doses were applied at 100% by soluble fertilizers. Regardless of the methods used, the total N absorption dramatically decreased when the dosage was cut by 50%. The control plot, where no fertilizer was used, had the lowest nitrogen concentration (67.71 kg N ha^{-1}) (Table 3). Similar observations made by [18] in rice and [19] in mustard.
Anywhere 100% soluble fertilizers were employed compared to conventional fertilizers, there was a substantially enhanced absorption of total phosphorus regardless of the methods utilized. The highest phosphorus absorption by maize kernel was achieved with the 100 percent STCR dosage applied using soluble fertilizer (27.28 kg P ha^{-1}; Table 4), followed by the LMH technique (25.55 kg P ha^{-1}). Because of the nutrients' improved solubility, more even distribution across the root zone, and greater solubility of soluble fertilizers, the same treatment had the maximum overall absorption (38.03 kg P ha^{-1}) in the study. Similar observations were made by [20].
In comparison to all other treatments, with the exception of the 100% STCR dose applied through conventional fertilizer treatment, uptake of potassium by maize kernel (29.72 kg $ha^{-1)}$ and stover (77.61 kg ha^{-1}) was significantly higher in the 100% STCR dose applied through soluble fertilizers (Table 5). This resulted in a significantly higher total uptake of potassium (107.34 kg ha^{-1}) by maize. In comparison to the LMH method and RDF, the STCR technique has demonstrated greater K adoption across the various approaches. This was primarily caused by the STCR approach's delivery of a greater dosage of potassium (86.67 kg K_2O ha^{-1}), which may have contributed to the increased absorption. The increased solubility, uniform distribution of nutrients, and increased effectiveness of water-soluble fertilizers may all contribute to this enhanced K absorption [12]. Similar outcomes were obtained by [21] who came to the conclusion that drip fustigation with 100% RDF through WSF registered considerably

Table 3. Uptake of nitrogen by kernal and stover as influenced by different forms of fertilizers and approaches of nutrient recommendation (kg ha^{-1})

Treatments	Kernal		Pooled	Stover		Pooled	Total		Pooled
	2012	2013		2012	2013		2012	2013	
T_1: Control	59.53	28.18	**43.86**	26.74	25.23	**25.99**	81.80	53.41	**67.61**
T_2 : 100 % RDF through CF	119.06	90.73	**104.90**	34.64	33.48	**34.06**	158.18	124.21	**141.19**
T_3 : 100 % RDF through SF	130.41	100.69	**115.55**	39.40	39.32	**39.36**	153.34	140.01	**146.67**
T_4 : 50 % RDF through SF	95.29	63.52	**79.40**	33.86	27.98	**30.92**	126.81	91.50	**109.15**
T_5 : 100 % LMH dose through CF	129.58	102.71	**116.14**	40.64	38.86	**39.75**	163.78	141.56	**152.67**
T_6 : 100 % LMH dose through SF	145.17	106.36	**125.76**	39.60	38.00	**38.80**	181.32	144.36	**162.84**
T_7 : 50 % LMH dose through SF	111.63	80.06	**95.85**	25.99	29.31	**27.65**	143.16	109.38	**126.27**
T_8 : 100 % STCR dose through CF	146.88	110.71	**128.80**	57.19	42.71	**49.95**	208.85	153.41	**181.13**
T_9 : 100 % STCR dose through SF	167.82	113.19	**140.51**	65.13	44.34	**54.73**	230.23	157.53	**193.88**
T_{10} : 50% STCR dose through SF	123.66	95.20	**109.43**	43.42	39.34	**41.38**	172.52	134.54	**153.53**
SEm±	**4.50**	**6.36**	**5.51**	**1.83**	**4.46**	**3.41**	**1.83**	**4.46**	**6.85**
CD (5%)	**13.36**	**18.90**	**15.80**	**5.43**	**13.25**	**9.77**	**5.43**	**13.25**	**19.65**

Table 4. Uptake of phosphorus by kernal and stover as influenced by different forms of fertilizers and approaches of nutrient recommendation (kg ha^{-1})

Treatments	Kernal		Pooled	Stover		Pooled	Total		Pooled
	2012	2013		2012	2013		2012	2013	
T_1: Control	16.43	5.72	**11.08**	10.21	1.90	**6.05**	26.64	7.62	**17.13**
T_2 : 100 % RDF through CF	27.85	11.70	**19.77**	14.48	2.95	**8.71**	42.32	14.65	**28.49**

T_3 : 100 % RDF through SF	34.10	15.15	**24.62**	15.37	3.38	**9.37**	49.47	18.53	**34.00**
T_4 : 50 % RDF through SF	25.43	10.81	**18.12**	13.20	2.83	**8.02**	38.62	13.65	**26.14**
T_5 : 100 % LMH dose through CF	30.25	14.47	**22.36**	15.13	3.35	**9.24**	45.38	17.82	**31.60**
T_6 : 100 % LMH dose through SF	35.36	15.74	**25.55**	18.06	3.52	**10.79**	53.42	19.26	**36.34**
T_7 : 50 % LMH dose through SF	29.37	13.68	**21.52**	14.18	2.88	**8.53**	43.56	16.56	**30.06**
T_8 : 100 % STCR dose through CF	30.98	13.71	**22.35**	15.50	3.41	**9.45**	46.48	17.12	**31.80**
T_9 : 100 % STCR dose through SF	38.29	16.27	**27.28**	17.77	3.73	**10.75**	56.07	20.00	**38.03**
T_{10} : 50% STCR dose through SF	29.92	12.94	**21.43**	12.15	2.62	**7.39**	42.08	15.57	**28.82**
SEm±	**1.37**	**0.95**	**1.18**	**0.85**	**0.24**	**0.62**	**1.09**	**0.24**	**1.08**
CD (5%)	**4.08**	**2.82**	**3.38**	**2.51**	**0.73**	**1.79**	**3.23**	**0.73**	**3.11**

greater leaf NPK content than did fertigation with conventional fertilizers and attributed it to the increased fertilizer usage efficiency.

Chemical parameters of soil

The available nitrogen concentration in the soil varied significantly between the treatments. Regardless of differing application methods, the available nitrogen content of the soil did not substantially change between the soluble and traditional fertiliser-applied treatments (Table 6). This is because an equivalent quantity of nitrogen was delivered in the most soluble form even in conventional fertilizers. When 100% STCR dosage (T_9) was treated using soluble fertiliser, the accessible nitrogen content of the soil was much higher (189.02 kg ha^{-1}), on par with $T_5$and T_8, when traditional fertilizers were applied using LMH and STCR techniques, respectively. The larger dosage of nitrogen applied in these treatments was primarily responsible for the higher accessibility of nitrogen. [22] made a similar discovery about more nitrogen being available, which he attributed to the use of more fertilizer in conjunction with FYM. With a 100% STCR dosage administered using soluble fertilizers, the soil's accessible phosphorus level was notably high (131.43 kg P_2O_5 ha^{-1}). Orthophosphate is the most common form of P in solutions; however, minor quantities of organic P may also be present. P must be in the form of orthophosphate for plants to absorb it. The only pool that has any quantifiable mobility is the solution phosphorus pool, which is significant since it is the pool from which plants absorb phosphorus (P).

The majority of the P absorbed by a crop over the course of a growing season will likely have traveled only about an inch or less through the soil to reach the roots. If the soluble P pool were not constantly refilled, a developing crop would rapidly exhaust its supply of P. The amount of phosphate in the solution decreases when plants take up phosphate, and some phosphate from the active P pool is also released. The active P pool is the primary source of P that is accessible for crops since the solution P pool is so limited. Soil is fertile for phosphate when the active P pool in the soil can replenish the soil solution P pool [23].

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Nutrient use efficiency and apparent recovery

The treatment of soluble fertilizers at 50% of the STCR dose resulted in the highest nitrogen utilization efficiency (0.64 kg kg^{-1}), followed by soluble fertilizers applied at 50% of the LMH approach (Figure 1). As nitrogen application rates increase, the efficiency of nitrogen use eventually declines. These findings are consistent with those of [25], who found that increasing N doses resulted in a decrease in N efficiency, which they theorized might be caused by higher N losses brought on by thicker dressings.The 50% of STCR dose administered through soluble fertilizer ($T1_0$) showed the highest apparent recovery of phosphorus (1.13 kg kg^{-1}), followed by the 100% of STCR dose applied through soluble fertilizer (T_9) with the lowest apparent recovery of phosphorus (0.99 kg kg^{-1}). The rate of phosphorus application was higher in the RDF and LMH approaches than in the STCR technique. The enhanced efficiency may have been brought on by the maize crop's increased phosphorus uptake when phosphorus was applied in lesser quantities. The application of soluble fertilizers at 50% of the STCR dose (T_{10}) resulted in the maximum apparent potassium recovery (0.99 kg kg^{-1}), followed by 100% of the STCR dose (0.76 kg kg^{-1}). The lowest apparent recovery of potassium (0.72 kg kg^{-1})was observed when 100 per cent of RDF was applied through

Table 5. Uptake of potassium by kernal and stover as influenced by different forms of fertilizers and approaches of nutrient recommendation (kg ha^{-1})

Treatments	Kernal		Pooled	Stover		Pooled	Total		Pooled
	2012	2013		2012	2013		2012	2013	
T_1: Control	17.02	7.77	**12.40**	46.91	31.95	**39.43**	65.26	39.73	**52.50**
T_2 : 100 % RDF through CF	29.06	15.87	**22.46**	52.30	55.67	**53.98**	81.36	71.53	**76.45**
T_3 : 100 % RDF through SF	33.80	22.84	**28.32**	55.43	68.87	**62.15**	89.23	91.72	**90.47**
T_4 : 50 % RDF through SF	22.91	14.55	**18.73**	52.19	47.41	**49.80**	75.10	61.96	**68.53**
T_5 : 100 % LMH dose through CF	29.59	19.12	**24.35**	53.10	62.25	**57.67**	82.69	81.37	**82.03**
T_6 : 100 % LMH dose through SF	34.61	21.95	**28.28**	53.92	69.35	**61.64**	88.53	91.31	**89.92**
T_7 : 50 % LMH dose through SF	29.94	17.51	**23.72**	48.37	48.86	**48.61**	76.31	66.37	**71.34**
T_8 : 100 % STCR dose through CF	30.34	20.90	**25.62**	70.89	67.69	**69.29**	101.23	88.59	**94.91**
T_9 : 100 % STCR dose through SF	35.74	23.70	**29.72**	80.80	74.43	**77.61**	116.55	98.13	**107.34**
T_{10} : 50% STCR dose through SF	31.70	18.17	**24.93**	60.96	65.49	**63.22**	92.66	83.66	**88.16**
SEm±	**1.06**	**1.17**	**1.12**	**1.32**	**6.69**	**4.82**	**2.02**	**7.19**	**5.28**
CD (5%)	**3.13**	**3.49**	**3.20**	**3.93**	**19.88**	**13.83**	**6.01**	**21.36**	**15.15**

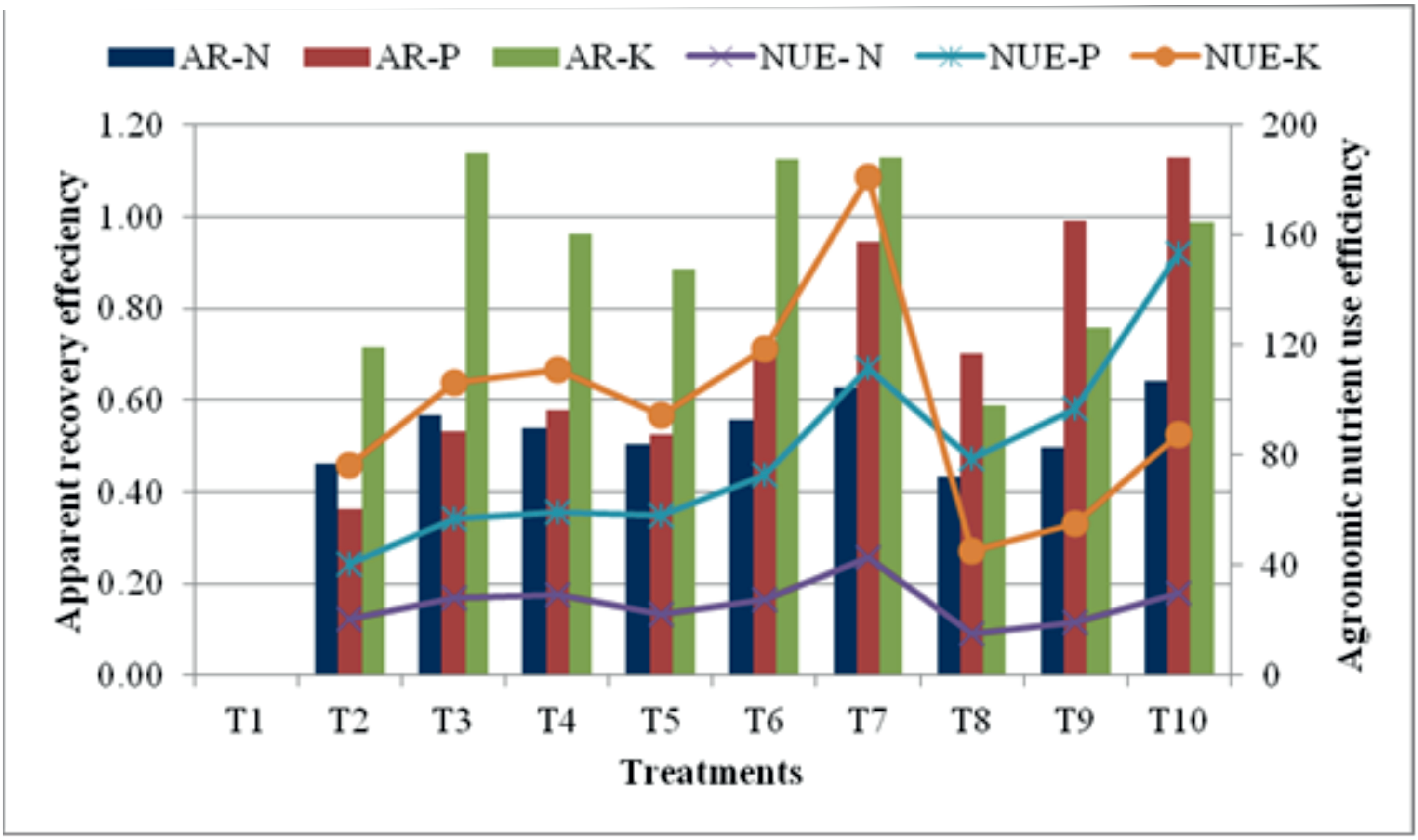

Fig 1. Apparent recovery efficiency (kg increase in nutrient uptake per kg nutrient applied) and agronomic nutrient use efficiency (kg increase in kernel yield per kg nutrient applied) of N, P, and K as influenced by different forms of fertilizers and approaches of nutrient recommendations

conventional fertilizers (T_2). These results are in conformity with the findings of [21].

Yield response and economics

The treatment where conventional fertilizers were applied using 100% of the LMH technique (T5) had the highest value cost ratio (VCR) of 8.17 and a yield response of 48.43 q ha^{-1} (Table 7). When soluble fertilizers were treated using 100% of the STCR dose (T_9) and a yield response of 58.43 q ha^{-1}, the lowest value-cost ratio of 1.16 was observed. With a value-cost ratio of 2.05, 50% RDF applied by soluble fertilizers (T_4) had the lowest yield response, 32.71 q ha^{-1}.

It was mainly because water-soluble fertilizers are very expensive on the market compared to conventional fertilizers. The 100 percent STCR dose administered using soluble fertilizer was found to have the highest response yardstick (227.48 kg kg^{-1}), followed by the same dose given using traditional fertilizers (225.89 kg kg^{-1}). [26] discovered that the equations were valid if the desired yield was obtained with a fluctuation of no more than 10%. Despite lower yields than soluble fertilizer treatments, regardless of various methods, the highest VCR was found in the

Table 6. Effect of different forms of fertilizers and approaches of nutrient recommendations on available N, P_2O_5, K_2O status (kg ha^{-1}) of soil after harvest of maize crop

Treatments	Available nitrogen		Pooled	Available phosphorus		Pooled	Available potassium		Pooled
	2012	2013		2012	2013		2012	2013	
T_1: Control	169.63	122.88	**146.26**	64.23	68.13	**66.18**	108.48	114.80	**111.64**
T_2 : 100 % RDF through CF	214.93	139.53	**177.23**	69.36	76.98	**73.17**	153.87	133.87	**143.87**
T_3 : 100 % RDF through SF	213.21	136.59	**174.90**	67.95	80.54	**74.25**	149.25	131.47	**140.36**
T_4 : 50 % RDF through SF	204.90	130.49	**167.70**	62.57	72.92	**67.74**	111.18	129.13	**120.16**
T_5 : 100 % LMH dose through CF	216.34	141.20	**178.77**	74.74	79.03	**76.88**	155.10	134.93	**145.02**
T_6 : 100 % LMH dose through SF	213.31	138.33	**175.82**	74.15	75.70	**74.93**	150.86	144.00	**147.43**
T_7 : 50 % LMH dose through SF	206.08	133.12	**169.60**	67.49	79.83	**73.66**	123.55	146.13	**134.84**
T_8 : 100 % STCR dose through CF	218.23	141.93	**180.08**	77.68	86.78	**82.23**	173.63	151.33	**162.48**
T_9 : 100 % STCR dose through SF	224.42	153.63	**189.02**	81.21	90.83	**86.02**	170.28	169.20	**169.74**
T_{10} : 50% STCR dose through SF	209.06	133.97	**171.52**	73.92	80.57	**77.25**	141.65	129.20	**135.43**
SEm±	**4.03**	**4.09**	**4.06**	**2.34**	**3.52**	**2.99**	**3.75**	**9.91**	**7.49**
CD (5%)	**11.98**	**12.16**	**11.65**	**6.94**	**10.46**	**8.57**	**11.14**	**29.45**	**21.49**

Table 7: Maize crop response, response yardstick and value cost ratio of maize crop production as influenced by different forms of fertilizers and approaches of nutrient recommendations

Treatment	Kernal yield	Yield response	RYS	VCR
	(q ha^{-1})		(kg kg^{-1})	
T_1: Control	34.74	-	-	-
T_2 : 100 % RDF through CF	65.18	40.85	158.05	6.69
T_3 : 100 % RDF through SF	77.26	53.03	160.00	3.59
T_4 : 50 % RDF through SF	56.94	32.71	86.30	2.05
T_5 : 100 % LMH dose through CF	72.66	48.43	164.69	8.17
T_6 : 100 % LMH dose through SF	82.12	57.89	166.16	1.91
T_7 : 50 % LMH dose through SF	70.95	46.72	94.82	2.69
T_8 : 100 % STCR dose through CF	73.68	49.45	225.89	7.60
T_9 : 100 % STCR dose through SF	82.66	58.43	227.48	1.16
T_{10} : 50% STCR dose through SF	72.54	48.31	121.20	1.79

Fertilizers rates kg^{-1} in Rs: N = Rs. 11.87, P_2O_5 = Rs. 47.60 and K_2O = 27.87 FYM = Rs. 800 t^{-1}, cost of maize = 2400 Rs q^{-1}
Soluble fertilizers rates kg^{-1} in Rs: 12:61:00 = Rs. 113.00, 24:24:00 = Rs. 170.62, 0:0:50 = Rs. 132.71
Calcium nitrate = Rs. 41.90

treatments where traditional fertilizers were applied. The lower cost of traditional fertilizers in comparison to soluble fertilizers was the primary factor contributing to the increase in VCR in these treatments. These fertilizers were less expensive primarily because of government subsidies.

CONCLUSION

Regardless of the various methods employed, higher kernel and stover yields were seen in soluble fertilizer applied treatments. The STCR method by LMH recorded the highest yields out of all the other approaches. In soluble fertilizers applied plot with 100% STCR dose and a very good yield response, the maximum kernel and stover yields of maize were noted. Irrespective of the various methods, reduced VCR was nevertheless observed whenever soluble fertilizers were used. This lower VCR in the plots where soluble fertilizers were applied was primarily driven by the very high cost of these fertilizers and the lack of any subsidies compared to conventional fertilizers. It is possible to preserve 50% of the nutrients in these fertilizers and attain yield levels higher than those obtained by using 100% conventional fertilizer if these soluble fertilizers are encouraged by giving subsidies equal to those given to conventional fertilizers.

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