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Studies on Fertilizer Use Efficiency in Ragi (*Eleusine coracana* L.) Under Rainfed Conditions

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A field experiment was conducted on alfisols during 2013 of Zonal Agricultural and Horticultural Research station, college of Agriculture, Navile, shimoga. To study the fertilizer use efficiency in ragi (*Eleusine coracona L.*) under rainfed conditions. A total of nine treatments were tried in a Randomized Complete Block Design (RCBD) with three replications. The treatments comprise of RDF + compost 10 t ha^{-1}, RDF + 50 % NK + compost 10 t ha^{-1}, STCR based NPK + compost 10 t ha^{-1}, STL based NPK + compost 10 t ha^{-1},RDF through enriched compost, RDF + 50% NK through enriched compost, STCR based through enriched compost, STL based through enriched compost, with a control. The results revealed that application of STCR based NPK and compost 10 t ha^{-1} for targeted yield 40 q ha^{-1} recorded a highest grain yield (3238.00 kg ha^{-1}) and straw yield (8926.00 kg ha^{-1}). The percent deviation for targated yield of 40 q ha^{-1} (19.05 %).Similarly higher uptake was recorded in STCR based NPK + compost 10 t ha^{-1} both in grain and straw. However, the NUE and AUE was highest in STCR based NPK and compost 10 t ha^{-1} for targeted yield 40 q ha^{-1}. The highest physiological use efficiency was recorded in control plot (no fertilizer). The highest partial factor productivity was recorded in STCR based NPK + compost 10 t ha^{-1}. The STCR approach was better for achieving the higher yield and higher nutrient use efficiency.

Key words*:* Soil test crop response (STCR); Targated yield; Nutrient use efficiency; Agronomic use efficiency.

Finger millet (*Eleusine coracona* (L.) *Garten*.), ranks third in importance among millets in the country in area (2 million ha) and production (2.8 million tonnes) after sorghum and pearl millet (Anon., 2001). One of the striking features which make finger millet an important dry land crop is its resilience and ability to withstand adverse weather conditions when grown in soils having poor water holding capacity. Finger millet is a staple food of millions of people in India and Africa especially for working class and also an ideal food for patients suffering from diabetes. The grains are high in calcium and iron besides being rich in carbohydrates and proteins.

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The major finger millet growing states in India are Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Jharkhand, Maharashtra and Uttaranchal, Karnataka state has the largest area of around 1.3 million ha (54% of the total area) and has a share of 60 per cent total production in India and productivity of 1325 kg per hectare followed by Maharastra, Orissa, Tamil Nadu, Andhra Pradesh and Uttaranchal, each having 10-12 per cent of the area.

Ragi ranks third both in area and production next only to the sorghum and rice. Among the various methods of fertilizer recommendation, the one based on targeted yield approach is unique in the sense that this method not only indicates the soil test based fertilizer dose,. Targeted yield concept strikes a balance between fertilizing the crop and fertilizing the soil. The theoretical basis and experimental proof for the fact that Liebig's law of minimum operates equally well for N, P, and K from the basis for fertilizer application for targeted yields (Ramamoorthy et al., 1967).

Judicious use of fertilizers is one of the most important means to obtain higher yields. For efficient and economic use, it is necessary to have information on the optimum doses of fertilizers and organics based on soil testing for different soils. Therefore, fertilizer recommendation aim at providing balanced nutrition to crops in order to produce maximum yield. Such balanced fertilization is ensured through soil testing and it increases the efficiency and economy in fertilizer use. Continuous use of inorganic nutrients source will adversely affect soil physico-chemical properties and thereby decline crop yields. In order to sustain the yield and reduce the dependence on inorganic fertilizer use, conjunctive use of organic manures and fertilizer is very much essential. The present investigation are aimed at prescription based fertilizer applications on soil test basis for specific yield targets of ragi to recommended to the farmers for judicious use of fertilizers for sustainable crop production. Hence objective of this study was evaluate the impact of different application rates of fertilizers on biomass, yield, nutrient uptake and nutrient use efficiency in ragi under rainfed condition.

MATERIALS AND METHODS

A field experiment was conducted on alfisols during 2013 of Zonal Agricultural and Horticultural Research station, college of agriculture, navile, shimoga, which is located at a latitude of 13^0 58' 30.4 north, a Longitude of 75^0 34', the climate of the study area in general is tropical wet and dry summer type. The mean maximum temperature was (33.70^0 C) in the month of april and minimum temperature occurs in December with value being 14^0 C. The mean annual rainfall of the region is 842.33 mm,. During this season, I have take Ragi has been taken as rainfed crop. The ragi crop cv.GPU28 was sown in june 2013 keeping the plants to plants distance of 22.5 cm and row spacing of 30 cm, following standard package of practices. A total of nine treatments were tried in a Randomized Complete Block Design (RCBD) with three replication. The treatments comprise of RDF + compost 10 t ha^{-1}, RDF + 50 % NK + compost 10 t ha^{-1}, STCR based NPK + compost 10 t ha^{-1}, STL based NPK + compost 10 t ha^{-1},RDF through enriched compost, RDF + 50% NK through enriched compost, STCR based through enriched compost, STL based through enriched compost, with a control.

The compost was applied 4-5 weeks before sowing of the ragi crop. NPK were applied in the form of urea, single superphosphate and muriate of potash. Full dose of P, K and half dose of N was applied at the time of sowing and half dose of N was top-dressed at 21 days after sowing of ragi crop. Representative soil samples (0-15 cm) were collected from each of the 27 plots before application of fertilizer and compost for sowing of ragi crop. The initial soil properties were analyzed and the soils within the experimental area. Soil texture was sandy loam in nature where clay content 13.72% (Table1). The bulk density was 1.52 Mg m^{-3}, the soil pH moderate and no salt problem was detected in the soil. Soil organic carbon content was 4.20 g Kg^1. The CEC was 6.53 cmol(P^+)kg^{-1} .

The soil sample were analyzed for available N before sowing of the crop by alkaline $KMno_4$ method of Subbiah and Asija (1956) and 0.5 M $NaHCO_3$ extractable P (Olsen *et al.* 1954nium acetate). Available K in soils was extracted by neutral normal ammonium acetate (hanway and Heidal 1952) and determined flame photo metrically the compost was digested and analyzed for per cent N, P, and K content following standard procedures. On average well decomposed compost contain 061% N, 0.4% P_2O_5, and 0.6% k_2O, respectively. The crop observations like date of occurrence of important phonological stages, biomass, yield and yield components, as influenced by different rates of nutrients , were recorded. The plot-wise yield data for grain and straw were recorded at the harvest of ragi crop.

At the time of harvesting from each plot five plants were selected for grain and straw sampling. The plants were analyzed for N by micro-Kjeldahal method (Jackson 1973) and N uptake was calculated by multiplying dry matter with content (%) of plant. The P and k in plant sample were analyzed after digestion with diacid (HNO_3: $HClO_4$)

digest was estimated by vanadomolybdate phosphoric acid yellow color method (jackson 1973) using spectrophotometer. Potassium content in the acid digest was measured using flame photometer and total uptake was calculated. With the help of nutrient uptake data and soil test values, the basic data (nutrient requirement in Kg t^{-1} of grain, per cent contribution from soil and applied fertilizer) were computed by Ramamoorthy *et al.* (1967). The basic data, in turn, was transformed into simple workable fertilizer adjustment equations for calculating fertilizers N,P and K doses for yield targets based on initial soil test values.

RESULTS AND DISCUSSION

Application of fertilizer by different approaches in combination with organic manures increased grain and straw yield significantly over control (Table 2). Application of fertilizer based on STCR (T_3) produced maximum ragi grain (3238.00 kg ha^{-1}) and, which was35.72 per cent higher over control (2385.70 Kg ha^{-1}). The highest ragi grain yield in T_3 was statistically on par with T_2 (3062.00 Kg ha^{-1}) and T_7 (3012.70 Kg ha^{-1}) treatments. The increase in yield might be due to improvement in yield and components for better partitioning of carbohydrates from leaf to reproductive parts and efficiency of applied nutrient in the soil resulting in increased yield in finger millet. The deviation was further reduced when fertilizer and compost were applied on STCR basis, thus minimum deviation was observed (19.05%) from targated yield 40 q ha^{-1}. The lower deviation might be due to better response to applied nutrients on STCR basis in presence of organic manures indicating the importance of balanced nutrition of crops. These results are conformity with findings of Apoorva *et al.* (2010).

The lowest straw yield was recorded (6616.00 Kg ha^{-1}) in control plot (Table 2) where as the highest straw yield (8926.00 Kg ha^{-1}) was recorded with application of STCR based NPK and compost 10 t ha^{-1}. The increase in straw yield was due to application of higher dose of major nutrients supply and subsequently uptake of nutrients by

Table 1. Initial soil properties of the experimental site

Parameters	Values
Physical properties	
Soil order	*Typic Haplustalf*
Sand (%)	78.00
Silt (%)	8.00
Clay (%)	14.00
Textural of soil	Sandy Loam
Bulk density (Mg m^{-3})	1.52
Chemical properties	
pH (1:2.5)	6.00
EC (dS m^{-1}) at 25^0	0.04
Organic Carbon (g kg^{-1})	4.20
CEC [cmol (p^+)Kg^{-1}]	6.53
Available N (kg ha^{-1})	190
Available P_2O_5 (kg ha^{-1})	180
Available K_2O (kg ha^{-1})	223
Available S (ppm)	9.50

Table 2. Effect of organic and different levels of inorganic nutrients of Grain and straw yield of ragi

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	% Deviation in grain yield from the target	% increase in grain yield over control
T_1 - RDF + Compost @ 10 t ha^{-1}	2892.30	7572.00	-27.69	21.23
T_2 - RDF+ 50 % NK + Compost @ 10 t ha^{-1}	3062.00	8500.00	-23.45	28.34
T_3 -STCR Based NPK + Compost @ 10 t ha^{-1}	3238.00	8926.00	-19.05	35.72
T_4 -STL Based NPK + Compost @ 10 t ha^{-1}	2938.70	8210.00	-26.53	23.17
T_5 -RDF through Enriched Compost	2735.30	7211.00	-31.61	14.65
T_6 -RDF + 50% NK through Enriched Compost	2940.30	8201.00	-26.49	23.24
T_7 -STCR Based through Enriched compost	3012.70	8329.00	-24.68	26.28
T_8 -STL Based through Enriched Compost	2848.30	7720.00	-28.79	19.39
T_9 -Control	2385.70	6616.00	_	_
SEm±	134.71	249.12		
C.D @5%	403.89	746.90		

crop which was responsible for better growth and dry matter accumulation. Similar results were reported by Ramesh *et al.* (2007).

The nitrogen uptake increased with advancement in age and the maximum was recorded at harvest stage by ragi grain (Table 3) in T_3 (29.52 kg ha^{-1}), straw (69.62 kg ha$^{-1)}$ and this lead to higher total uptake of nitrogen in T_3 (99.14 kg N ha^{-1}) due to application of STCR based NPK and compost @ 10 t ha^{-1} for a targeted yield 40 q ha^{-1} compared to others. Increased uptake of nutrient in plant system is a consequence of availability of nutrients synergistic relationship between organic manure and chemical fertilizer. Similar pattern of nutrient uptake due to synergistic effect between organic and inorganic sources was reported by Subramanian and Aproorva *et al.* (2010). The P uptake increased with aging of ragi crop (Table 3) and maximum was recorded at harvest stage in grain (22.01 kg ha^{-1}), straw (58.01 kg ha^{-1}) and the total uptake in same treatment T_3 (80.02 kg P ha^{-1}). The application of STCR based NPK and compost @ 10 t ha^{-1} recorded significantly higher P uptake among all the treatments.

The higher p uptake was due to the influence of organic and inorganic acid produced during decomposition of organic material in soils resulted in mineralizing the insoluble phosphate

Table 3. Effect of organic and different levels of inorganic nutrients on primary total nutrient uptake by ragi grain and straw

Treat No	Treatments	Uptake (kg ha^{-1})		
		N	P	K
T_1	RDF + Compost @ 10 t ha^{-1}	76.71	55.21	76.32
T_2	RDF + 50 % NK + Compost @ 10 t ha^{-1}	91.99	74.05	88.95
T_3	STCR Based NPK + Compost @ 10 t ha^{-1}	99.14	80.02	94.73
T_4	STL Based NPK + Compost @ 10 t ha^{-1}	86.26	63.42	84.50
T_5	RDF through Enriched Compost	75.59	55.06	71.85
T_6	RDF + 50% NK through Enriched Compost	86.46	64.50	83.51
T_7	STCR Based through Enriched compost	89.60	68.71	86.10
T_8	STL Based through Enriched Compost	81.76	62.71	74.50
T_9	Control	64.66	47.52	56.80
	SEm±	4.66	1.88	2.83
	C.D @5%	13.99	5.63	8.49

Table 4. Effect of organic and different levels of inorganic nutrients on nutrient use efficiency (N, P, K) in ragi at harvest

Treatments	Nutrient Use Efficiency (%)			Total
	N	P	K	
T_1-RDF + Compost @ 10 t ha^{-1} (111:80:86)	10.86	9.61	22.70	14.17
T_2-RDF+ 50 % NK + Compost @ 10 t ha^{-1} (136:80:98)	20.10	33.16	32.81	27.39
T_3-STCR Based NPK + Compost @ 10 t ha^{-1}(158:48:94)	21.82	67.71	40.35	34.97
T_4-STL Based NPK + Compost @ 10 t ha^{-1} (111:67:86)	19.46	23.38	32.21	24.60
T_5-RDF through Enriched Compost (111:80:86)	9.85	9.43	17.50	12.10
T_6-RDF + 50% NK through Enriched Compost (136:80:98)	16.03	21.23	27.26	20.86
T_7-STCR Based through Enriched Compost (158:48:94)	15.78	44.15	31.17	25.14
T_8-STL Based through Enriched Compost (111:67:86)	15.41	22.34	20.58	18.86
T_9-Control	-	-	-	0.00
SEm±	1.61	0.94	1.73	0.83
C.D @5%	4.89	2.87	5.24	2.54

NUE = (Nutrient Uptake in treated plot – Nutrient uptake in control plot / Nutrient applied X100) into more soluble phosphate the results evident from finding of Veeranagappa (2010). Significantly higher K uptake by ragi grains in T_3 (16.19 kg ha^{-1}), straw (78.54 kg ha^{-1}) and higher total uptake of potassium in the T_3 (94.73 kg ha^{-1}) was recorded with application of STCR based NPK and compost @ 10 t ha^{-1} for a targeted yield of 40 q ha^{-1} due to addition of compost resulted in the extraction of more K by millet crop when compared to control. The increase in potassium uptake with organic sources of FYM was due to the priming effect that organic on decomposition release organic acids which solubilise native i.e., fixed and non-exchangeable form of K and change the soil solution with potassium ions at later stage of crop growth (Sri Ranjitha *et al.,* 2013).

Effect of organic and different levels of inorganic nutrients on nutrient use efficiency

The use efficiency of total major nutrients indicates clearly that T_3 recorded higher use efficiency (Table 4). Even on individual nutrient basis i.e. N, P and K separately the same treatments holds the key with higher use efficiency. The nutrient efficiency gradually decreased with increase in the application rates. In general the nitrogen use efficiency of a crop shows declining trend with increasing levels of N application. The phosphorus use efficiency was highest in treatment STCR based NPK + compost @ 10 t ha^{-1} in T_3 (67.70 %). Phosphorus application based on STCR approach very low quantity (48 kg ha^{-1}) because of high initial content in soil. The increase in uptake

Table 5. Effect of organic and different levels of inorganic nutrients on agronomic and physiological use efficiency of grain yield of ragi in comparison to control

Treatments	AUE			PUE		
	N	P	K	N	P	K
T_1-RDF + Compost @ 10 t ha^{-1} (111:80:86)	4.57	6.34	5.90	37.70	52.39	37.90
T_2-RDF+ 50 % NK + Compost @ 10 t ha^{-1} (136:80:98)	4.98	8.46	6.91	33.29	41.35	34.42
T_3-STCR Based NPK + Compost @ 10 t ha^{-1} (158:48:94)	5.40	17.77	9.07	32.66	40.46	34.18
T_4-TL Based NPK + Compost 10 @ t ha^{-1} (111:67:86)	4.98	8.13	6.43	34.07	46.34	34.78
T_5-RDF through Enriched Compost (111:80:86)	3.15	4.38	4.07	36.19	49.68	38.07
T_6-RDF + 50% NK through Enriched Compost (136:80:98)	4.08	6.94	5.66	34.01	45.59	35.21
T_7- STCR Based through Enriched Compost (158:48:94)	3.97	13.06	6.67	33.62	43.85	34.99
T_8-STL Based through Enriched Compost (111:67:86)	4.17	6.81	5.38	34.84	45.42	38.23
T_9-Control	-	-	-	39.89	50.19	41.99
SEm±	0.40	0.68	0.49	1.05	1.92	1.15
C.D @5%	1.23	2.08	1.30	3.13	5.76	3.46

* AUE: Agronomic use efficiency = $GY_T - GY_C$ / Nutrient applied
* PUE: Physiology use efficiency = GY / Nutrient uptake

Table 6. Nutrient uptake and yield difference over RDF in different treatments

Treatments	ND (kg ha^{-1})			UD (kg ha^{-1})			YD (kgha^{-1})	
	N	P	K	N	P	K	Grain	Straw
T_1-RDF + Compost @ 10 t ha^{-1}	-	-	-	-	-	-	-	-
T_2-RDF + 50 % NK + Compost @ 10 t ha^{-1}	25.00	0.00	12.00	15.28	18.84	12.63	169.70	928.00
T_3-STCR Based NPK + Compost @ 10 t ha^{-1}	47.00	-32.00	8.00	22.43	24.81	18.41	345.70	1354.00
T_4-STL Based NPK + Compost @ 10 t ha^{-1}	0.00	-12.00	0.00	9.55	8.21	8.18	46.40	638.00
T_5-RDF through Enriched Compost	0.00	0.00	0.00	-1.12	0.15	4.47	157.00	361.00
T_6-RDF + 50% NK through Enriched Compost	25.00	0.00	12.00	9.75	9.29	7.19	48.00	629.00
T_7-STCR Based through Enriched compost	47.00	-32.00	8.00	12.89	13.50	9.78	120.40	757.00
T_8-STL Based through Enriched Compost	0.00	-12.00	0.00	5.05	7.50	-1.82	-44.00	148.00
T_9- Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* ND: Nutrient difference *UD: Uptake difference YD: Yield difference

of phosphorus by ragi crop was noticed when application of phosphorus was in smaller quantity which might have caused in higher efficiency. The potassium use efficiency also showed similar results to that of phosphorus. It was higher at lower rate of application. In STCR based approach the potassium application recorded higher biomass production and resulted in higher uptake of K. these results are in conformity with Raina et al. (2011). However, the potassium use efficiency found higher than the nitrogen are presented in and Fig 1, which supports the theory that K is catalytic and enzymatic in nature rather than involving in structural development (Tisdale et al., 1990).

Effect of organic and different levels of inorganic nutrients on agronomic and physiological use efficiency of grain yield of ragi in comparison to control

The data presented in Table 5 pertain to agronomic nutrient use efficiency (ANUE) and physiological nutrient use efficiency (PNUE) for applied nutrients of ragi crop. They are significantly higher in treatment T_3. On the other hand lowest AUE as well as PUE was found in T_1 and T_5 (4.18 kg kg^{-1}). Application of STCR based NPK + compost 10 t ha^{-1} registered better agronomic nitrogen use efficiency because of synchronized supply of N. Finally, it is recognized that efficiency of added nitrogen would increase when other nutrient are also in adequate supply for crop growth. In general cereal crops showed linear response to a lower fertilizer inputs and quadratic response thereafter as reported by Ramesh et al. (2007).

The agronomic and physiological phosphorus and potassium use efficiency of ragi crop were significantly higher in treatments T_3 (STCR based NPK + compost 10 t ha^{-1}) as compared to other treatments. The lowest was recorded in the T_5 (RDF through enriched compost).This is due to lower phosphorus application but higher agronomic use efficiency in STCR approach because initial soil phosphorus is very high.

Further, precise calculation were made for both agronomic and physiological use efficiency (Table 6) by considering the nutrient application uptake pattern of crop and yield difference of treatments to that of RDF (T_1). Interestingly, the per se incremental effect of nutrient on yield and uptake was encouraging. It was found clearly that 136 and 158 kg N ha^{-1} the response was linear. The response at addition of 20 kg N ha^{-1} over RDF was 4.00 kg kg^{-1} (agronomic efficiency) and further additional application of 46 kg N ha^{-1} enhanced the response to 15.03. The trend remained same for all.

CONCLUSION

Currently this technology is being focused through frontline demonstrations to farmer's, which revealed that higher benefit: cost ratio was much higher in case of fertilizer treatments based on this methodology as compared to the fertilizer doses based on general recommended dose or local farmer's practice. Therefore equation developed could be used for making fertilizer recommendation for targeted yield of ragi in alfisols . fertilizer recommendation based on this concept are more quantitative, precise and meaningful. Keeping in view the poor socio-economic condition of the farmers with very low income, a yield target of 40 q ha^{-1} was taken so that even at very low input cost farmer can achieve economical yield target. In this, farmer can choose the yield target according to their resources and management conditions.

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