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Use of STCR targeted yield approach to increasing nutrient use efficiency in eggplant (*Solanum melongena* L.)

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Abstract
A field experiment was conducted at ZARS, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka to study the effect of optimal rates of nutrient fertilizers through different approach in eggplant production to increase the nutrient use efficiency. The results revealed that the significantly higher fruit yield (37.81 t ha^{-1}) was noticed in soil test crop response (35 t ha^{-1}) with IPNS approach compared to inorganic treatment (35.98 t ha^{-1}) with same target. The significantly higher straw yield (66.49 q ha^{-1}) was observed in STCR-IPNS (35 t ha^{-1}) followed by STCR-IPNS (30 t ha^{-1}) treatment (63.73 q ha^{-1}). Similarly, significantly higher nutrient uptake was recorded in STCR-IPNS approach followed by inorganic treatment. Whereas, LMH and POP approaches recorded lower nutrient uptake compared to STCR approach due to application of lower dose of fertilizers. The highest nitrogen (13.89 q fruit kg^{-1} N) use efficiency (ANUE) was observed in LMH approach. Whereas, in POP approach recorded 12.86 q fruit kg^{-1} N where 125 kg N ha^{-1} was applied. This might be due lower uptake of nitrogen by eggplant in LMH approach compared to STCR approach. The P and K nutrient efficiency was highest in STCR-IPNS (30 t ha^{-1}) followed by LMH approach. The highest respond yard stick (RYS) was recorded in STCR-IPNS lower target compared to higher target and other approaches. The performance of eggplant for sustaining the soil fertility status through balanced nutrition was achieved in STCR approach.

Keywords: STCR, Eggplant, Nutrient use efficiency

Introduction
Fertilizer nutrient recommendations are usually given for different crops by taking into consideration the soil available nutrient status which is being categorised as low, medium and high. Among the various methods of fertilizer recommendations, the soil test crop response (STCR) approach is one of the most scientific approach of nutrient application for crops by using the soil test values and targeted yield equations. These equations are developed by considering the contribution of nutrients from soil, manures and fertilizers. In this study, STCR fertilizer prescription equation was developed under irrigated conditions by following the standard procedures of gradient and main experiment (Ramamoorthy *et al.*, 1969) [8]. It is necessary to add fertilizer inputs to the soils in order to have good and continuous crop yields. Such nutrients may be either organic or inorganic in form depending on their availability of sources. However, soil testing and its response would be a useful tool when it is based on intimate knowledge of soil-crop-variety-fertilizer-climate and management practices and its interaction.

Targeted yield concept strikes a balance between fertilizing the crop and fertilizing the soil. The procedure provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. In the targeted yield approach, it is assumed that there is a linear relationship between grain yield and nutrient uptake for the crop. Eggplant (*Solanum melongena* L.) a member of Solanacea family, is one of the most common vegetable crops grown in Karnataka, India. Because it is highly lucrative, farmers can afford high inputs and other crop management facilities to achieve high yield and profits. Eggplant is a staple vegetable; its nutritive value varies among varieties (vitamin A and B). In order to provide farmers with science-based nutrient management practices, the objective of this study was to determine the optimal rates of nutrient fertilizers through different approach in eggplant production to increase the nutrient use efficiency.

Materials and Methods
The field experiment was carried out at Zonal Research Centre, GKVK, Bengaluru. After laying out the field plan, soil samples were drawn from each treatment from experimental site.

Based on the soil test values (Table 1) NPK fertilizers were applied in STCR and LMH approach. However, in package of practice (POP) treatment recommended dose of FYM + NPK (50:40:25 kg NPK ha^{-1}) was applied. The soil in study was slightly acid (pH 6.39) with soil organic matter content 0.45 per cent, available N: 260 kg ha^{-1}, available P_2O_5: 61 kg ha^{-1} and available K_2O: 151 kg ha^{-1}, respectively. The soils were relatively abundant in P and marginal in nitrogen and potassium. Soil samples collected from the experimental plots after crop harvest were processed and analysed for available nitrogen, phosphorus and potassium by following standard procedures (Jackson, 1973) [6]. After analysing the major nutrient concentrations in grain and straw samples uptake of these nutrients by eggplant, agronomic nutrient use efficiency (ANUE), response yard stick (RYS) and value-cost ratio (VCR) were computed by using the standard formulae. The data collected with respect to yield, nutrient uptake and available nutrient status were subjected to statistical analysis. The level of significance used in F and t-test was P= 0.05. Critical difference (CD) values were calculated for P= 0.05 whenever F-test was found significant.

Results and discussion

Eggplant fruit yield was significantly influenced by fertilizer nutrient applications (Table 2). STCR (35 t ha^{-1}) approach was recorded significantly higher fruit yield (37.81 and 35.98 in IPNS and inorganic approach, respectively) compared to other treatments. STCR (30 t ha^{-1}) approach was recorded slightly lower fruit yield (36.82 and 33.48 in IPNS and inorganic approach, respectively) compared to STCR higher target. The STCR approaches gave higher yield in both target, IPNS approach and inorganic approach in both lower and higher targets, whereas in POP and STL approach yields were on par with each other. The increase in yield due to application of nutrients with FYM based on soil test values which attributed to the increase flowering and fruit yield. The application of too higher dose of fertilizer (183%:130%:142%) in STCR-35 t ha^{-1} target as compared to lower target and other treatments which mainly influence on the yield and its attributing characters. Though the local eggplant variety potentiality was low (25 to 30 t ha^{-1}) in local areas, that's why in this experiment fixed a higher yield target (35 t ha^{-1}) which directly effect on the higher fertilizer nutrient recommendation. The higher yields from organic materials plus inorganic fertilizer treatments than sole inorganic fertilizer treatment is an indication that integrated use or organic and inorganic nutrient sources advantageous over the use or inorganic fertilizer alone (Suge *et al*. 2011 and Ullah *et al.,* 2008) [10, 11]. In STCR approach application of nitrogen at 230 kg ha^{-1} which is almost double the recommended dose of fertilizer though, the application of fertilizer was higher there is no any toxicity was noticed. Bobadi and Van, 2003[4] also reported that application of N at 200 kg ha^{-1} recoded good yield over control and at lower dose of N.

Significantly higher straw yield (66.49 q ha^{-1}) was recorded in STCR-IPNS treatment followed by STCR-Inorganic treatment (63.17 q ha^{-1}). The straw yield was low (63.44 and 63.73 in inorganic and IPNS approach, respectively) in lower target (30 t ha^{-1}) compared to higher target. Whereas, POP (60.43 q ha^{-1}) and STL (61.80 q ha^{-1}) approaches were on par with each other. The lowest straw yield was recorded in control treatment (37.64 q ha^{-1}). However, all the treatments were significantly superior over control which doesn't because this treatment which does not received any fertilizer nutrients. Increases in inorganic fertilizer additions tended to increase number of vegetative growth compared with the unfertilized control. Addition of organic manures had a significant effect on growth of eggplants expressed by their height and fresh weight compared to their controls. Soils which have sufficient organic carbon provide more the nutrients compared to unsupplied plots. Organic manure normally contains complex compounds and provide not only a variety of nutrients but also add to the most important constituent of the soil, humus which provides excellent substrate for plant growth. The slow or gradual release of nutrients by organic fertilizers is called the additive effect of organic fertilizers. This is in contrast to inorganic fertilizers that release nutrients rapidly and may fit the plant demand during the crop growth. Due to improved soil properties it enables the roots to grow deeper ensuring strong stems and taller plants which intern effect on the better flowering and fruit yield.

Nutrient uptake

Uptake of nitrogen by eggplant fruit was highest (96.11 kg N ha^{-1}) in STCR-IPNS 35 t ha^{-1} target followed by STCR inorganic treatment with same target. Application of recommended dose of fertilizer significantly higher nitrogen uptake by fruit over control treatment. The nitrogen uptake by straw was highest in IPNS higher target followed by lower target. Whereas in control treatment lowest uptake was recorded. The higher fruit (34.54 kg ha^{-1}) and straw (29.53 kg ha^{-1}) phosphorus uptake was recorded in STCR-IPNS treatment followed by STCR inorganic treatment. However, phosphorus uptake by fruit was highest compared to plant dry matter. This might be due to application of 115 kg P ha^{-1} with 25 t FYM ha^{-1} which directly influence on the concentration in fruit followed by dry matter which intern effect on the total uptake by eggplant in STCR-IPNS treatment. Agbede *et al.*, 2008 [1] reported similar results and explained that addition of suitable organic manure in the soil improves the soil physical and chemical properties which encourages better root development, increased nutrient uptake and water holding capacity which leads higher fruit yield and better fruit quality. It is well known that increased growth requires more of both N and P, indicating that mutually synergistic effects result in both growth stimulation and enhanced uptake of the two nutrients.

The potassium uptake by fruit was almost double compared to plant dry matter. Significantly higher fruit uptake was noticed in the STCR-IPNS treatment (128.82 and 68.67 kg K ha^{-1} in fruit and dry matter, respectively) followed by STCR-inorganic, LMH and package of practice approach. Whereas control plot recorded lower levels of potassium uptake in both fruit and dry matter.

Nutrient use efficiency

The highest nitrogen (13.89 q fruit kg^{-1} N) use efficiency (ANUE) was observed in treatment which received only 133 kg N ha^{-1} in LMH approach. Whereas, in POP approach recorded 12.86 q fruit kg^{-1} N where 125 kg N ha^{-1} was applied. This might be due lower uptake of nitrogen by eggplant in LMH approach compared to STCR approach. In STCR integrated approach lower target recorded higher (12.33 q fruit kg^{-1} N) N efficiency compared to higher target (9.68 q fruit kg^{-1} N) followed by STCR inorganic approach. The obtained results were in agreement with Bobadi and Van (2003) [4]. The nitrogen use efficiency gradually decreases with increase in N application rates (Saeid and Manochehr,

2010 and Basavaraja *et al.*, 2016) [9, 3]. The phosphorus nutrient use efficiency was highest in STCR-IPNS (30 t ha^{-1}) treatment and lowest was recorded in STCR (35 t ha^{-1}) inorganic treatment. This was due to application of lower rate phosphorus (85.76 kg ha^{-1}) as compared to STCR (35 t ha^{-1}) inorganic plot (129.83 kg ha^{-1}). Potassium nutrient use efficiency was higher (37.86 q fruit kg^{-1} K) in STCR-IPNS with lower target (32.23 q fruit kg^{-1} K at 30 t ha^{-1}) compared to higher target. Whereas, in POP and LMH approach K use efficiency was 32.15 and 36.73 q fruit kg^{-1} K, respectively. The higher K use efficiency might be due to application of lower level of K nutrient compare to at higher target in STCR approach. The application of potassium influences nitrogen use efficiency at higher levels of N application. The application of 20 kg K_2O resulted in a yield increase of rice (3 q ha^{-1} at 40 kg N level). However, the increase was three times more as N level increased from 40-120 kg/ha at the same K level (Biswas and Prasad, 1991).

Postharvest soil nutrient status

The available nitrogen, phosphorus and potassium status of soil after harvest of eggplant crop as influenced by different approaches of fertilizer applications is depicted in Table 3. Significantly higher available nitrogen (272.53 kg ha^{-1}) was noticed in STCR-inorganic (30 t ha^{-1}) treatment, in this treatment there is increase in nitrogen (5 %) over the initial soils. All other treatments were on par with each other except the control (235.2 kg N ha^{-1}) in which no fertilizers were applied. Nitrogen is an essential part of proteins and nucleic acids, as well as of the chlorophyll molecule (Taiz and Zeiger, 2004) this might influence in efficiently utilized the applied nitrogen by eggplant, therefore there is not much increase in nitrogen content in post-harvest soils, though the treatments received almost double the recommended N nutrient. The available phosphorus content was significantly higher (85.23 kg ha^{-1}) in STCR-IPNS targeted with (35 t ha^{-1}) IPNS approach compared to POP (61.48 kg ha^{-1}) and LMH approach (55.55 kg ha^{-1}). Application of higher fertilizer as per the soil test based yield target of eggplant the requirement of P was high in STCR approach compared to the other approach this might be directly effect on the available P content at harvest. The percent increase over the initial was highest in STCR approach. The increase was to the tune of 15 per cent (STCR-inorganic @ 35 t ha^{-1}) to 58 per cent (STCR-inorganic @ 35 t ha^{-1}). Available potassium content was significantly higher in integrated approach compared to inorganic approaches. The highest potassium was noticed in STCR-IPNS target 30 t ha^{-1} (162 kg ha^{-1}) followed by STCR-IPNS target 35 t ha^{-1} (131.60 kg ha^{-1}). Overall the potassium content in postharvest soils decreased from initial level this might be due to the total uptake by eggplant was higher than the applied nutrient which might be directly effect on the availability of potassium content in soil.

Response yard stick and value cost ratio

The highest response yard stick (RYS) was observed in LMH treatment (6.89) followed by STCR-IPNS (30 t ha^{-1}) treatment (6.53). Whereas, lowest RYS was noticed in STCR inorganic (30 t ha^{-1}) treatment. The applied fertilizers in LMH approach was efficiently utilized by crop though the higher RYS was recorded. In the STCR approach based on the soil test yield target basis recommendation of fertilizer for eggplant was higher compared to package of practice, this applied dose was not much effectively utilized by eggplant due to this reason the RYS was less in higher target STCR approach compared to other approaches. The highest value cost ratio (VCR) of 2.20 was recorded in the STCR-inorganic treatment with lower target (Table 3). Whereas, lowest VCR was recorded in POP treatment. The VCR was highest in inorganic treatment due to application of lower dose of fertilizer based on soil test value without FYM which intern directly effect on the cost of fertilizer without FYM cost, this directly effect on the value cost ratio. In IPNS treatment, the cost of fertilizer with addition of FYM cost, the total cost will be more this will contribute to low VCR (Santi *et al.*, 2002 and Basavaraja *et al.*, 2017).

Table 1: Details of initial soil test values and nutrients applied to eggplant

Treatments	Initial Soil test value			Nutrients applied		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	kg ha^{-1}			kg ha^{-1}		
STCR(35 t ha^{-1})	256.48	61.91	156.40	229.90	129.83	71.17
STCR (35 t ha^{-1}) [Integrated]	272.16	53.85	170.40	210.67	115.46	63.53
STCR(30 t ha^{-1})	258.72	61.91	145.60	173.07	106.80	58.51
STCR (30 t ha^{-1}) [Integrated]	266.19	67.00	151.60	158.91	85.76	52.60
POP	263.95	72.51	152.40	125.00	100.00	50.00
LMH (STL)	290.08	63.18	157.60	133.33	83.33	50.00
Control	260.59	55.55	132.80	0.00	0.00	0.00

Table 2: Influence of different approaches of fertilizer recommendation on eggplant fruit yield, straw yield, fruit and dry matter uptake

Treatments	Fruit Yield (t ha^{-1})	Straw Yield (q ha^{-1})	Fruit uptake (kg ha^{-1})			Dry matter uptake (kg ha^{-1})		
			N	P	K	N	P	K
STCR(35 t ha^{-1})	35.98	63.17	95.21	33.13	118.76	103.03	27.83	58.51
STCR (35 t ha^{-1}) [Integrated]	37.81	66.49	96.11	34.54	128.82	108.79	29.53	68.67
STCR(30 t ha^{-1})	33.48	60.44	85.45	30.17	103.90	100.47	23.08	45.58
STCR (30 t ha^{-1}) [Integrated]	36.82	63.73	89.50	33.77	122.13	103.81	25.64	60.04
POP	33.49	60.43	83.55	30.08	109.12	94.35	24.88	53.01
LMH (STL)	35.78	61.80	79.85	32.78	119.94	95.21	24.08	45.61
Control	19.34	37.64	51.57	17.78	68.39	55.84	15.49	27.54
S.E.m±	1.16	3.36	4.81	1.86	8.56	5.31	3.07	10.83
$CD_{0.05}$	3.31	9.57	13.70	5.30	24.39	15.13	8.75	30.86

Table 3: Influence of different approaches of fertilizer recommendation on eggplant Agronomic nutrient use efficiency (ANUE), post-harvest soil nutrients, respond and dry matter uptake

Treatments	Agronomic Nutrient use efficiency (q kg^{-1})			Post-harvest soil nutrients (kg ha^{-1})			Respond yard stick	VCR
	N	P	K	N	P_2O_5	K_2O		
STCR(35 t ha^{-1})	8.10	14.27	26.17	242.20	71.66	103.60	4.31	2.05
STCR (35 t ha^{-1}) [Integrated]	9.68	17.68	32.23	261.33	85.23	131.60	5.23	0.82
STCR(30 t ha^{-1})	9.31	15.04	27.48	272.53	78.44	110.40	4.75	2.20
STCR (30 t ha^{-1}) [Integrated]	12.33	22.84	37.86	242.40	80.99	162.00	6.53	0.85
POP	12.86	16.08	32.15	268.80	61.48	110.40	5.85	0.70
LMH (STL)	13.89	22.68	36.73	238.93	55.55	128.00	6.89	0.82
Control	0.00	0.00	0.00	235.20	67.42	82.40	-	-
S.E.m±	0.92	1.87	3.10	15.81	8.04	14.56	-	-
$CD_{0.05}$	2.61	5.34	8.84	45.07	22.91	41.50	-	-

Conclusion

Nutrients application through STCR approach is superior over the other approach, in achieving the higher vegetative and productivity of eggplant towards higher yield and benefit. Though the application of fertilizer were higher in STCR approach than the other approaches, overall nutrient use efficacy of eggplant was higher to achieve maximum yields. However, the yield targets under STCR approach should be fixed based on the genetic potentiality of the eggplant to maximize production potentiality of crop. The performance of eggplant for sustaining the soil fertility status through balanced nutrition was achieved in STCR approach.

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