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Research Article

Fertilizer prescription model through soil test crop response approach for carrot *(Daucus carota)* on an Alfisols of Southern India

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ABSTRACT

Fertilizer requirements for the crop should be based on yield response to the added fertilizer nutrient, nutrient requirements of a crop, nutrient supply from indigenous sources, and the fate of added fertilizers to the soil in the short and long term. In the above context, field experiments were conducted at, the University of Agricultural Sciences, Bangalore from Kharif 2013 to 2015in three phases. Soil test data, yield and nitrogen (N), phosphorus (P), and potassium (K) uptake by carrot crop were used for achieving four important basic parameters, viz., nutrient requirement, the contribution of nutrients from fertilizers (%C-F), soil (%C-S), and organic manure (%C-OM) to develop the targeted yield equation and these equations were validated in comparison with soil test laboratory (STL) approach and general recommended dose (GRD). It was found that 0.76, 0.42, and 0.79 kg of N, P2O5, and K2O respectively were required for producing one quintal of carrot. The STCR approach, with or without FYM, at the target yields 25 and 22 t ha-1 enhanced the carrot root yield over the general recommended dose and STL approach. It also exhibited a higher N,P, and K use efficiency, along with better profitability. Thus, STCR-targeted yield approach could improve the yield, economics, and efficiency of nutrient use for carrots compared to GRD and STL approaches.

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1. INTRODUCTION

The benefits of increased use of fertilizers in achieving higher targets of food grain production is very well established. However, practicing farming with high-yielding crop varieties under present fertilizer constraints due to their ever-increasing prices, a viable proposition would be the adoption of economic and judicious fertilizer use and management practices so that the high investment in fertilizers is reaped adequately. The method of fertilizer recommendations based on soil tests and yield targets of the crops also called the "STCR targeted yield approach" is found to be a better approach to avoid wide variations in soil rating limits, as it substitutes the exact values for soil available N, P, and K [1].

Carrot is characterized by relatively moderate requirements for climate and soil. Owing to their modest needs for cultivation and storage, they can be produced freshthroughout the year and sold fresh. Carrot roots are rich in nutrients with moisture 86 g, protein 0.9 g, carbohydrate 10.6 g, fat 0.2 g, fiber 1.2 g, energy 48-kilo calories, mineral 1.1 g, iron 2.2mg, beta carotene 9.81 mg, thiamine 0.04 mg, riboflavin 0.02 mg, niacin 0.5 mg, vitamin-C 3 mg, folic acid 15 mg, calcium 14 mg and phosphorus 19.8 mg per 100 g of edible portion [2]. Besides the importance of carrot in human life, its production has persistentlybeen low in most parts of the world. However, the main causes of low yields areassociated with inadequate knowledge on new production methods, appropriateagronomic practices and application of fertilizer without knowing the nutrient requirement [3]. In this context, the present study was conducted to develop a fertilizer prescription model for carrot based on targeted yield approach.

MATERIAL AND METHODS

Field experiments were conducted in three phase viz., (1) fertility gradient experiment with exhaustive maize crop (2) test crop experimentation with carrot, and (3) verification trial with carrot to validate the developed targeted yield equation. Field experiments were carried out at Zonal Agricultural Research Station, (Block No. I1) University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru located in the Eastern Dry Zone of Karnataka at 13° 04' 55.2'' N latitude, 77° 34' 10.0'' E longitude with an altitude of 930 meters above mean sea level. The region experiences wet and dry tropical savanna with moderately hot summers and comfortably cold winters. Average annual precipitation was about 844 mm in 2013, 988 mm in 2014, and 1076 mm in 2015. During 2013, mean minimum and maximum temperatures were 18.34°C and 29.47°C and the corresponding temperatures in 2014 were 29.60°C and 18.48°C, respectively and in 2015 were 29.30°C and 18.83°C respectively (Figure 1).

Physical and Chemical Properties of Experimental Soil

The soil of the experimental field was sandy loam in texture. They are taxonomically categorized as belonging to the Vijaypura series and a member of the fine mixed Isohyperthermic family of typic Kandic Paleustalfs. Before the start of the experiment, the soil of the experimental field had 240.40 kg ha-1 soil available alkaline potassium permanganate oxidizable N, 200.63 kg ha-1 Bray's- P2O5, 290.56 kg ha-1 neutral N ammonium acetate exchangeable K2O, 0.41 % organic carbon, pH 6.01 and electrical conductivity of 0.32dS m-1 in 1:2.5 soil to suspension ratio [4]. Experimental soil was low in soil available N, high in soil available P2O5, and medium in soil available K2O. DTPA-extractable [5] Fe, Mn, Zn, and Cu were analyzed and found in the sufficiency range.

Fertility gradient trial

The field trial was conducted during Kharif 2013 to develop a variation in soil available-N, P, and K before the test crop experiment. For this, the whole field area was divided into three equal strips. These strips were fertilized with three levels of N, P2O5, and K2O (0-0-0, 150-0-200, 300-0-400 kg ha-1 applied to strips I, II, and III, respectively) and three levels of farmyard manure (FYM) (5-10-20 t ha-1 applied to strip I, II, and III, respectively). The standard dose of nitrogen fertilizers was fixed based on the recommended dose of fertilizers for fodder maize (150 kg ha-1) and potassium doses were fixed based on K fixing capacity (200 kg ha-1) of soil. The P fixing capacity of the soil was found to be 135 kg ha-1. As the soil was high in available phosphorus content phosphorus fertilizer was not applied. The FYM used for the study contains 0.59% N, 0.30% P, and 0.55% K. An exhaustive crop of fodder maize (variety- African tall) was grown by adopting suitable agronomic practices to enable the applied fertilizer nutrients to undergo a transformation in the soil by plant and microbes. Fodder maize was harvested at 60 days after sowing and fodder yield was recorded. After the harvest of the fodder maize, soil samples (0–15 cm) were collected and analyzed to assess the development of the fertility gradient.

Test-crop trial and derivation of fertilizer prescription equations

The test crop trial was conducted during Kharif2014 with carrot as a test crop by dividing each fertility strip into three blocks of manure (F0 - No FYM, F1 -Recommended dose of FYM, F2 - Double dose of FYM), each of these manure blocks were divided into 8 subplots by considering seven different NPK combinations and one absolute control. So, a total of 21 treatments of NPK combination and 3 controls were imposed in each strip and making a total of 72 plots from three strips. Each fertilizer treatment combination was tested in three replication in a Randomized Block Design. The fertilizer treatments comprised N at the rate of 0, 37.50, 75, and 112.50 kg ha-1; P2O5 at the rate of 0, 31.50, 63 and 94.50 kg ha-1and K2O at the rate of 0, 25, 50 and 75 kg ha -1. Three levels of FYM at the rate of 0, 25 and 50 t ha-1 for F0, F1, and F2 block/strip respectively. After the layout, soil samples were again collected 0- 20 cm depth to determine the available N, P, and K of each experimental plot before sowing. The sources of N, P, and K were urea, single super phosphate, and muriate of potash, respectively. FYM was applied 15 days prior to sowing and the full amount of N, P, K, were applied at the time of sowing. The crop was raised as per the standard package of practice. Carrot root was recorded from all the plots and expressed in t ha-1.

Chemical analysis of soil and plant samples

The soil samples were air-dried and ground to pass through a 2 mm sieve and the available N was estimated by the alkaline KMnO4 method [6], available P content by Bray's extractant (i.e., 0.025 M HCl and 0.03 M NH4F) was determined colorimetrically by the ascorbic acid method [7] and available K by extraction with 1 N ammonium acetate (pH 7.0) and fed directly to flame photometer [8].

Plant samples were collected from each treatment, dried in the shade, and then in a hot air oven at 65°C. The plant samples were ground in a willey mill. N content in plant samples was determined by the micro Kjeldahl method [9]. Di-acid extract was prepared as per the standard method [4]. This di-acid extract was used to determine P and K content in the plant samples [4]. From the chemical analytical data, the uptake of each nutrient was calculated as shown below:

Nutrient uptake (kg ha-1) = Nutrient content (%) X dry weight in kg ha-1 / 100

From the data on soil test values, crop dry matter yield, and nutrient uptake, basic parameters like nutrient requirement (NR), the contribution of nutrients from the soil (C-S), fertilizer (C-F), and organic manure (C-OM) were calculated, using the standard formulae [10]. By using the basic parameters the fertilizer nutrient requisite for the targeted productivity of carrots was worked out

Verification trial

A field experiment was conducted to validate the soil test crop response (STCR) targeted yield equations developed in the main experiment for carrots in terms of yield, percent deviation from the fixed target, and economics in comparison with other approaches of fertilizer recommendations like Soil Test Laboratory (STL) approach and General Recommended Dose (GRD) and Farmers fertilizer practice (FFP) in a randomized block design (RBD) with three replicates. Treatment comprised of T1- STCR 25 t ha-1 (NPK alone), T2- STCR 25 t ha-1 (NPK + FYM), T3- STCR 22 t ha-1 (NPK alone), T4- STCR 22 t ha-1 (NPK + FYM), T5- General recommended dose, T6- Soil Test Laboratory approach, T7 – Farmers fertilizer practice and T8- Absolute control. A composite soil sample was collected at 0-20 cm depth from each plot after laying out the plan and before the start of the experiment. Based on the soil test values NPK fertilizers nutrients were applied for specific yield targets in STCR and soil test laboratory approaches. The crop was grown as per the standard agronomic practices and harvested at full maturity stage and the yield was computed from the net plot and expressed in t ha-1. Plant samples were collected from each treatment and analyzed for total NPK content by adopting the standard procedure and uptake was worked out. The Response Yard Stick (RYS), percent deviation and Value Cost Ratio (VCR) were computed by using the standard formulae as shown below [10].

$$\text{Percent deviation} = \frac{[\text{Actual yield obtained } (\text{kg ha}^{-1}) - \text{Targeted yield } (\text{kg ha}^{-1})]}{\text{Targeted yield } (\text{kg ha}^{-1})} \times 100$$

$$\text{VCR} = \frac{[\text{Yield in treated plot } (\text{t ha}^{-1}) - \text{Yield in control plot } (\text{t ha}^{-1})]}{\text{Cost of fertilizers and FYM applied to treated plot}} \times \text{Cost t}^{-1} \text{ of carrot}$$

Nutrient Use Efficiency

Nutrient (N/P/K) use efficiency parameters viz., Agronomic nutrient use efficiency (AE), and Recovery efficiency (RE) were calculated using the following formulae [11].

$$AE(kg\ kg^{-1}) = \frac{[\text{Carrot root yield in treated plot }(kg\ ha^{-1}) - \text{Carrot root yield in control plot }(kg\ ha^{-1})]}{\text{Fertilizer nutrient applied }(kg\ ha^{-1})}$$

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

Statistical analysis

The basic data from the test-crop experiment were used for developing fertilizer prescription equations. The main experiment data was analyzed using SPSS 16.0 software. The data of the validation trial were subjected to the analysis of variance (ANOVA) technique of randomized block design [12].

Results

Fertility Gradient Experiment

The mean post-harvest soil test values for N, P2O5, and K2O of the fertility gradient experiment indicated the variation with respect to soil fertility among the strips and is depicted in Figure 2. The mean soil available N, P2O5, and K2O were 226.70, 314.80, and 140.80 kg ha-1, respectively in the strip I, 230.20, 457.60, and 229.70 kg ha-1, respectively in strip II and 236.50, 593.90 and 328.20 kg ha-1, respectively strip III (Figure 2). The center of distribution for N, P2O5, and K2O were is lowest for strip I (225.40, 265.5, and 132.8 kg ha-1) compared to strip II and III. The whisker and half-box in strips I and III are somewhat longer on the upper side of the median than on the lower side, which causes the distribution of N and K2O in strips I and III to be positively skewed whereas the distribution of P2O5 is negatively skewed in strip III. Similarly, the distribution of N and P2O5 is positively skewed in the strip I and II whereas the skewness is negative for N and K2O in strip II. (Figure 2).

Test crop experiment

The mean and variation of plant uptake of N, P, and K nutrients and yield of carrots as influenced by fertilizer treatments are given Table 1. The mean root yield under main experiment followed the order strip III (8.42 t ha-1) > strip II (10.25 t ha-1) > strip I (17.49 t ha-1) with a variation of 21.04, 21.95 and24.01 percent in strip I, II and III respectively. A similar trend of results were noticed with respect to total uptake of NPKwith the variation of 22.71, 28.20 and 36.06 per cent for N; 21.82, 28.70 and 33.77 percent for P2O5; 23.62, 31.52 and 33.24 per cent for K2O in strip I, II and III respectively. The root yield of carrot had a strong correlation ($p < 0.001$) with total N uptake ($r2 = 0.985$), followed by total K uptake ($r2 = 0.970$) and total P uptake ($r2 = 0.945$) (Figure 3). Similarly, the crop responses to fertilizer N, P, K and FYM are depicted in Figure 4, which showed a significant ($p < 0.01$) carrot crop responseto fertilizer N, P and K application with the R2 values of 0.808 for N, 0.830 for P and 0.712 for K.

Basic parameters for equation development

The basic parameters required for developing fertilizer prescription equations are a) nutrient requirement in kg per quintal of economic produce (NR), b) per cent contribution of nutrients (NPK) from soil available nutrients (%C-S), c) per cent contribution from fertilizer nutrients (%C-F) and d) per cent contribution from organic manure (%C-OM). The amount of nutrient required to produce one quintal of carrot root yield was found to be 0.76 kg N, 0.42 kg P2O5 and 0.79 kg K2O. The contribution of nutrients from fertilizers for carrot crop was found to be 72.37, 84.24 and 90.34 %respectively as given in Table 2. The efficiencies of soil test values of nutrients were found to be 28.55% for N, 36.56% for P2O5, and 59.29% for K2O. Similarly, the contribution from FYM was found to be 0.16% for N, 0.12% for P2O5, and 0.46% for K2O.

Based on the basic parameters, the fertilizer prescription equations were calibrated for carrot crop to achieve a definite yield target. The equations derived were:

STCR- NPK alone	STCR (NPK + FYM)
F.N = 10.50T - 0.39SN	F.N = 10.50T - 0.39SN- 0.23OM
$F.P_2O_5$ = 4.90T - 0.43 SP_2O_5	$F.P_2O_5$ = 4.90T - 0.43 SP_2O_5- 0.14OM
$F.K_2O$ = 8.70T - 0.66SK_2O	$F.K_2O$ = 8.70T - 0.66SK_2O- 0.51 OM

Where, FN, FP2O5and FK2O are fertilizer N, P2O5and K2O in kg ha-1 respectively; T is the yield target in t ha-1; SN, SP2O5and SK2O are available soil nutrients in kg ha-1 respectively and OM is the amount of FYM (organic manure) added in t ha-1.

The derived fertilizer equations depicted that the ratio contribution of nutrients from the soil to fertilizer was higher for potassium (0.66:1) followed by phosphorus (0.43:1) and least for nitrogen (0.39: 1).

Validation trial

The yield of carrot under validation trial

A significantly higher carrot yield (27.51 t ha-1) was recorded in the STCR target of 25 t ha-1through NPK + FYM which was superior to all the other treatments. The yields in STCR targeted yield approach treatments were found to be superior over the Soil test laboratory approach (19.39 t ha-1), General recommended dose (19.28 t ha-1), and Farmer's fertilizer practice (19.18 t ha-1). The STCR-NPK + FYM treatment at both the targets (22 and 25 t ha-1) recorded a yield more than the target fixed and was higher compared to STCR-NPK alone.

Percent deviation

The percent deviation indicated the yield variation from the target fixed which is generally based on genetic potentiality of the crop (Table 3). The percent (%) deviation in the present study from the fixed target was found to be positive in STCR target of 25 and 22t ha-1through NPK + FYM (10.03% and 8.30% respectively) where the yield obtained was higher than the fixed targets and the lower deviation (-0.37% and -1.62% respectively) was noticed with STCR-NPK alone for the same yield targets. Similarly, a higher negative deviation was recorded in farmers' fertilizer practice (-4.07%), General recommended dose (-3.62%) and soil test laboratory approach (-3.05%) indicating that the crop could not achieve the genetic potential yield in these treatments.

Value cost ratio

The higher value cost ratio (VCR) of 43.30 was recorded where fertilizer nutrients were applied through STCR-NPK alone for a yield target of 25t ha-1 followed by 34.91 in STCR target of 22t ha-1 through NPK alone (Table 3). The lower value cost ratio of 1.78 was recorded with the application of nutrients based on Farmer's fertilizer practice. However, STCR-NPK + FYM treatments recorded lower VCR than the NPK alone treatments.

Nutrient use efficiency

The NUE as influenced by various approaches of nutrient management are depicted in Table 4. Nutrient management practices caused a variation in NUE under carrot production. In general, the STCR treatments had a higher nutrient use efficiency compared to the other treatments. The highest agronomic efficiency of nitrogen (AEN) occurred with an STCR target of 25t ha-1 through NPK + FYM treatment (26.10 kg kg-1)followed by an STCR target of 25t ha-1 through NPK alone (23.19 kg kg-1). The lowest AEN occurred in farmers' fertilizer practice (9.99 kg kg-1). The AEP and AEK were higher in STCR-based nutrient management practices than in the application of the general recommended dose of fertilizer and soil test laboratory approach. Similarly, the recovery efficiency of nitrogen (REN), phosphorus (REP) and potassium (REK) increased with STCR treatments compared to the application of the fertilizer nutrients based on STL approach and general recommended dose. The higher REN, REP, and REK were recorded for STCR approach with NPK + FYM treatments.

Discussion

The major aim of the fertility gradient experiment was to create significant variability with respect to soil available N, P and K prior to test crop experimentation. Increased availability of N, P and K in soil from strip I to III was due to fertilizer application in graded doses, thus creating a fertility gradient in the same field which is a prerequisite for conducting the main experiment. The results are in line with the findings of many researchers [13,24] who reported that after the harvest of maize crop in gradient experiment, the fertility increased from strip I to III. Maize has been found to develop a fertility gradient for the three major nutrients in each experimental strips as maize is an exhaustive crop causing over-mining of plant nutrients, thus leaving relatively stable nutrient sinks in the soil that resulted in creating the fertility gradient.The purposeful creation of fertility gradients by application of graded levels of N, P2O5 and K2O fertilizers was also observed on Inceptisol [14] Alluvial soils [15].

The yield and nutrient uptake relationship for carrot is depicted in Figure 2, showing a close association between crop yields and nutrient uptake with almost a linear relationship. The highest yield and uptake in the high fertility strip (strip III) was due to the overall highest nutrient application and also might be due to the creation of higher fertility status due to the gradient experiment. Irrespective of the strips (I/II/III), plots where NPK fertilizer was applied with FYM recorded higher yield and uptake, as compared to sole NPK fertilizer application which might be due to the direct effect of decomposition and mineralization of various nutrients from FYM and indirectly due to rhizosphere effect in increasing the microbial activity and its impact on the available nutrient content[16,17]. Similar outcomes were also reported in direct seeded rice [11] and under different conditions. An adequate dose of N application and enhanced absorption and accumulation resulted in higher yield and uptake (NPK), and there might have been sufficient availability of N fertilizer in the III strip which created a favorable N uptake. The possible reason behind the highest uptake of phosphorus in strip III was attributed to better root proliferation, having a graded P application [15]. The higher dose of N application stimulated the vegetative and root foraging capacity, meaning the crops require additional P and K, and increased the phosphorus uptake in the crops [20]. A similar trend was noticed with respect to potassium and might be attributed to the higher application of fertilizer potassium [15].

Soiltestcalibrationwasmadeforcertaindesiredyieldtargetsof carrot by targetedyieldmodelto optimizethefertilizerdosesbyusing thepre-sowingsoil test values, totalnutrientuptakeanddosesof fertilizer N,P2O5andK2O and organicmanure (intheformof FYM) applied.From this study it was observed that carrot requires1.81 times more of nitrogen and 1.88 times more of potassium in comparison with phosphorous [21]. Order of percentage contribution of fertilizer nutrient to total nutrient uptake was observed as K>P>N. These results indicate that nutrient contribution from fertilizer sources was greater than the soil source. The nutrient contributions from the fertilizer sources were greater than those from the soil source and fertilizer doses required for attaining a specific yield target of rice decreased with increasing soil test values [22]. Sizable contribution of NPK requirement through FYM was noticed towards the crop requirement which helps in saving of nutrients to be applied through costly fertilizers.

The developed targeted yield equations were validated in comparison with other approaches of fertilizer recommendation. The higher yield of yield in the treatment STCR target of 25t ha-1 through NPK + FYM might be due to the balanced application of nutrients which is based on soil analysis and takes into account the amount of nutrient removed by the crops, initial levels of soil fertility, efficiency of nutrients present in the soil and added through the fertilizers and the ability of targeted yield approaches to satisfy the nutrient demand of crop more [13]. Interestingly, the higher yield was recorded in STCR treatments at both the targets even without the application of phosphorus as soil was very high in phosphorus content indicating that the phosphorus fertilizer can be saved to a greater extent. These factors might have provided the optimum nutrients at optimum time for better uptake and ultimately resulted in higher dry matter and yield [23]. The increased yield at higher target with NPK + FYM compared to NPK alone was mainly due to integrated application of organic and inorganic fertilizers which might have released the nutrients readily in the plant available form, thereby increased the growth and yield of carrot. The percent deviation of yield was within ±10 percent variation proving the validity of the developed equations. The higher VCRunder STCR-NPK alone could be mainly due to the application of the required dose of NPK fertilizer without FYM associated with higher yields. Even though higher yields were recorded in STCR-NPK + FYM, the VCR was very low mainly due to high cost of FYM applied to these treatments. Similar results were reported in aerobic rice [23] and ragi [24]. The higher use efficiency of nutrients in the STCR approach could be attributed to the higher yield with lower rates of fertilizer application as per the requirement of the crop. An AEN of 6.8 – 34.2 and AEK of 28.4 – 55.3 in rice crops have been reported [11]. The relatively higher AE with an STCR-based application of fertilizers compared to common recommendations might be due to the balanced supply and efficient utilization of nutrients due to the synergistic effects of fertilizers and the applied FYM [23].

Conclusion

Based on this study, it can be concluded that the STCR targeted yield equations developed for carrot crop is most suitable for Alfisols for getting higher yield compared to all other approaches of fertilizer nutrient recommendation. Even though

VCR was lower in STCR integrated approach the due to high cost of FYM, these treatments should be recommended for applying a balanced dose of fertilizer nutrients in order to encourage the farmers to produce compost/FYM on their own to reduce the cost of production thereby the soil fertility can be sustained over a longer period and increase the economic returns to the farmers.

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Conflict of interest

The author reported no potential conflict of interest

Declaration of funding

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Table 1. Descriptive statistics of carrot yield and nutrient uptake under main experiment.

Strips		Root yield (t ha^{-1})	Total N uptake (kg ha^{-1})	Total P_2O_5 uptake (kg ha^{-1})	Total K_2O uptake (kg ha^{-1})
I	Range	5.10-11.85	23.27-57.08	9.29-21.11	69.03 – 152.40
	Mean ± SD	8.42±1.73	39.01±8.86	15.05±3.36	106.40 ±25.15
	(CV %)	21.04	22.71	21.82	23.62
II	Range	6.32-15.55	17.46-72.40	12.36-31.00	64.58 – 244.87
	Mean ± SD	10.25±2.25	44.39±12.52	19.38±5.57	128.93±40.65
	(CV %)	21.95	28.20	28.70	31.52
III	Range	9.63-25.34	17.63-87.47	9.85-36.49	71.18-269.11
	Mean ± SD	17.49±4.20	46.28±16.694	21.85±7.38	163.97±54.50
	(CV %)	24.01	36.06	33.77	33.24

Table 2. The basic data obtained from the test crop experiment

Parameters	N	P_2O_5	K_2O
NR (kg q^{-1})	0.76	0.42	0.79
C-S%	28.55	36.56	59.29
C-F%	72.37	84.24	90.24
CO-M%	0.16	0.12	0.46

Table 3. Influence of different approaches of nutrient recommendations on yield, % deviation, response yard stick (RYS) and value cost ratio (VCR) of carrot crop

Treatments	Nutrients added (kg ha^{-1})			Yield (t ha^{-1})	% Deviation	VCR
	N	P_2O_5	K_2O			
T_1: STCR 25 t ha^{-1} (NPK alone)	150.60	0.00	50.71	24.91^b	-0.37	43.30
T_2: STCR 25 t ha^{-1} (NPK + FYM)	151.60	0.00	31.61	27.51^a	10.03	6.74
T_3: STCR 22 t ha^{-1} (NPK alone)	101.19	0.00	84.16	19.68^d	-1.62	34.91
T_4: STCR 22 t ha^{-1} (NPK + FYM)	92.45	0.00	92.42	21.66^c	8.30	3.88
T_5: General Recommended Dose	75.00	63.00	50.00	19.28^d	-3.62	2.30
T_6: Soil Test Laboratory Approach	80.56	50.50	50.00	19.39^d	-3.05	2.40
T_7: Farmers Fertilizer Practice	92.60	159.00	0.00	19.18^d	-4.07	1.78
T_8: Absolute Control	-	-	-	14.75^e	-26.23	-

Table 4: Nutrient use efficiency in carrotas influenced by different approaches of fertilizer recommendation

Treatment	Nitrogen use efficiency		Phosphorus use efficiency		Potassium use efficiency	
	AEN	REN	AEP	REP	AEP	REP
T_1	23.19	0.24	10.03	0.06	35.72	0.46
T_2	26.10	0.35	12.37	0.08	48.25	0.58
T_3	13.25	0.18	5.32	0.04	20.77	0.37
T_4	17.49	0.25	7.19	0.05	30.23	0.50
T_5	10.24	0.17	4.52	0.04	20.15	0.32
T_6	11.09	0.15	4.27	0.05	19.07	0.45
T_7	9.99	0.12	3.87	0.03	22.39	0.11
T_8	-	-	-	-	-	-

AE: Agronomic efficiency; RE: Recovery efficiency

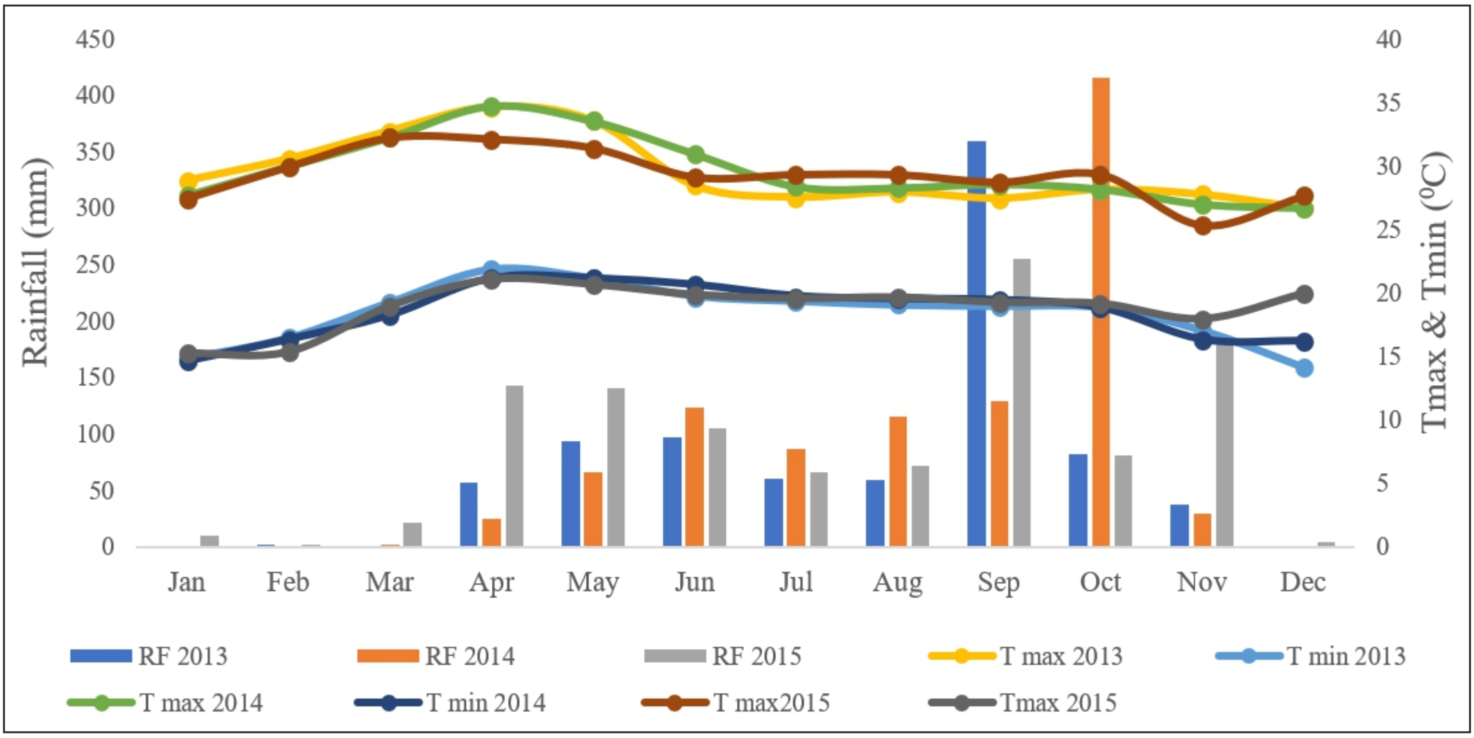


Figure 1. Variation in annual rainfall, maximum temperature and minimum temperature during the field experiments (RF: rainfall; T max: Temperature maximum; T min: Temperature minimum)

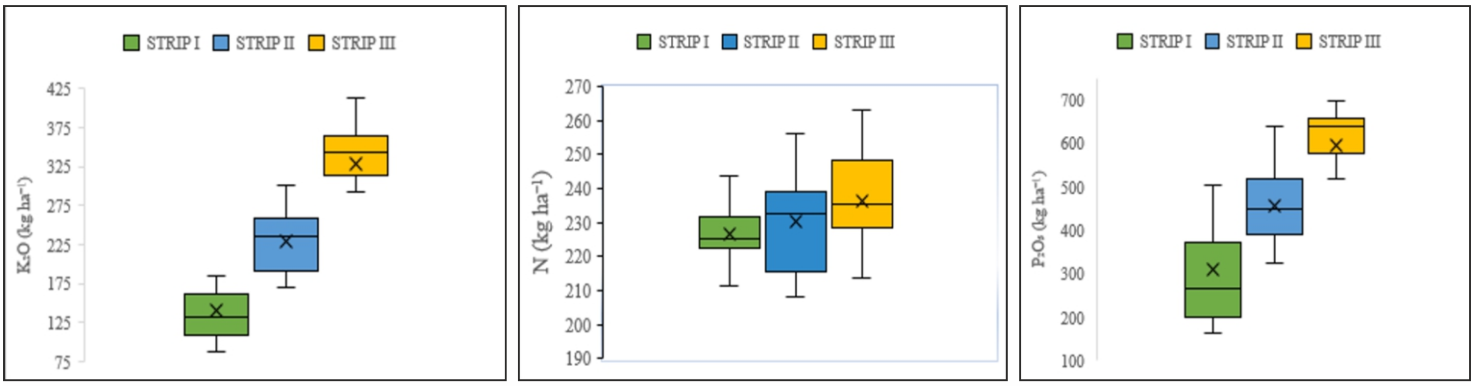


Figure 2. Box and whisker plots of the available soil nutrients (0–15), after the soil fertility gradient experiment.

The median is marked by a horizontal line inside the box. The ends of the box are the upper and lower quartiles. Whiskers end at the 5th and 95th percentiles. Minimum and maximum values are indicated by Whiskers and symbol × indicates the mean

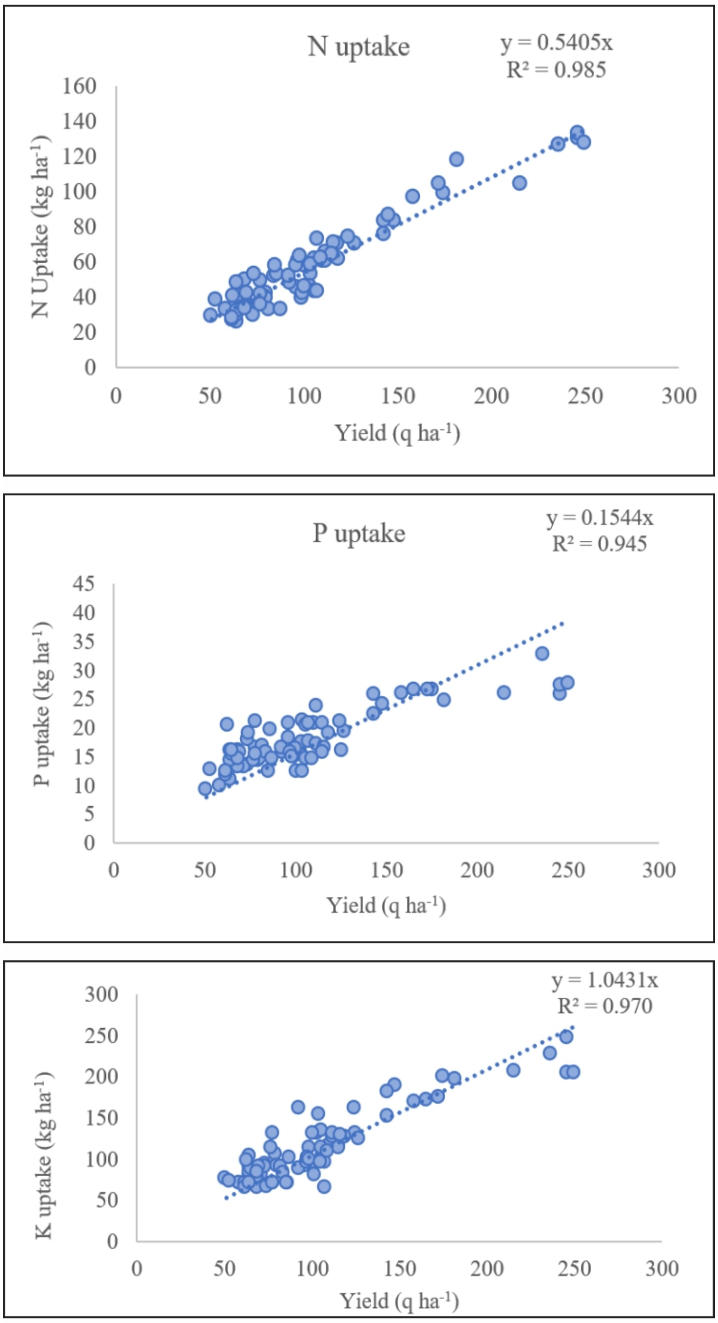
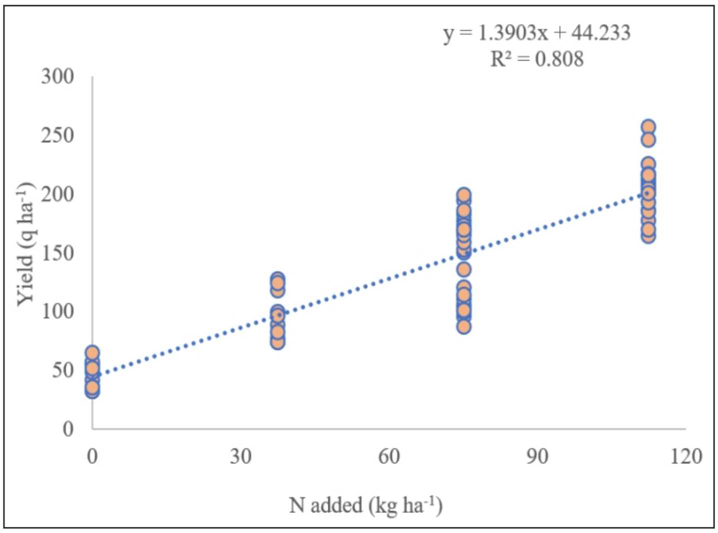


Figure 3. Linear correlations between yield and total N (a), P2O5 (b), and K2O (c) uptake by carrot in the test crop experiment



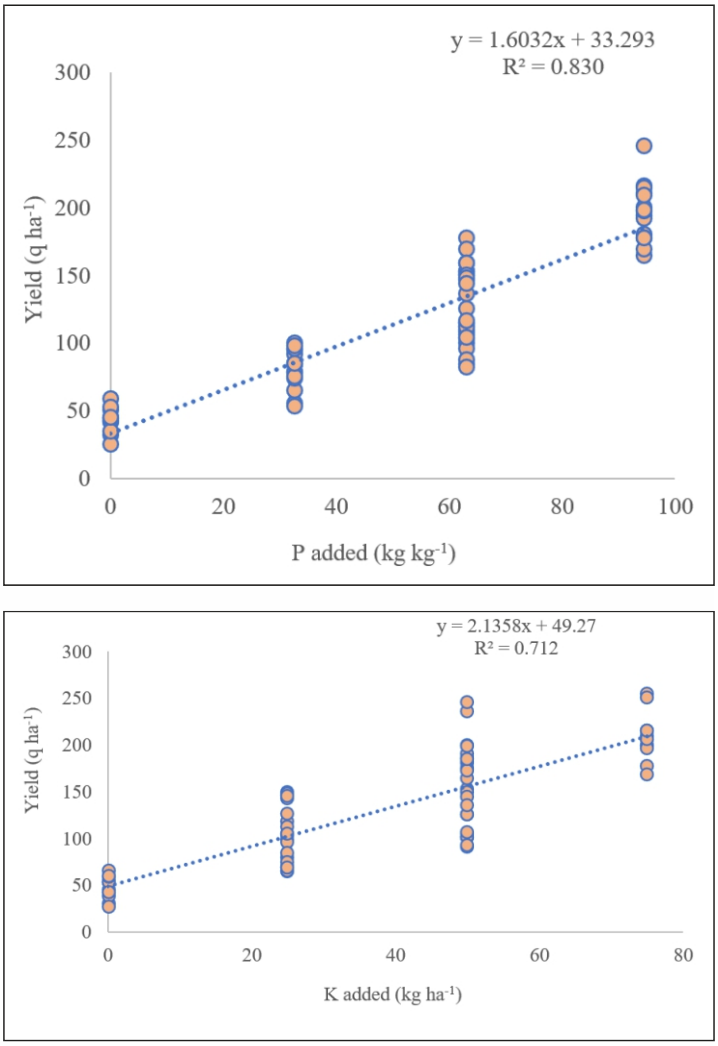


Figure 4. Relationship between carrot yield and N, Pand K doses

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