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Optimum Nutrient Requirement of Elephant Foot Yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) Under Coconut Gardens

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Abstract

Among the tropical tuber crops, elephant foot yam (EFY) (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is a highly potential and ideal intercrop for the coconut gardens of Kerala. Being highly efficient biologically with good yield potential to the tune of 30-100 t ha^{-1}, it is high nutrient demanding too. Though, there are different nutrient management approaches for the cultivation of this crop, taking into account both crop productivity as well as soil health, balanced nutrition based on soil nutrient status and crop requirement deserves special mention. In this regard, customization of nutrients specific to regions and crops can be considered as one of the key approaches. In the protocol for arriving at the grades of the customized fertilizer formulations, one component is evolving the actual optimum of all nutrients of a particular soil by conducting nutrient omission experiments for major nutrients and nutrient level experiments for secondary and micronutrients. Such experiments were conducted for elephant foot yam under intercropping in coconut gardens of the major tuber crops growing soils of Kerala viz., laterite (AEU 9) and sandy plains (AEU 3). The theoretical optimum (based on weighted average data of the soil test) was N : P : K : Mg : Zn : B : Dolomite @ 71 : 12.5 : 106.5 : 16 : 5.25 : 1.31 : 1000 (AEU 3) and 78 : 12.5 : 90 : 16 : 5.25 : 1.31 : 1000 kg ha^{-1} (AEU 9) respectively. The weighted average data of nutrients was 0.95 and 1.50% (organic carbon), 61.97 and 69.27 kg ha^{-1} (available P), 213.96 and 295.87 kg ha^{-1} (available K), 113.32 and 600.16 ppm (exchangeable Ca), 37.53 and 114.99 (exchangeable Mg), 5.07 and 21.46 ppm (available S), 3.94 and 5.68 ppm (available Zn), 0.70 and 0.82 ppm (available B), 1.79 and 3.79 ppm (available Cu), 101.20 and 64.66 ppm (available Fe) and 18.82 and 37.65 ppm (available Mn) respectively for AEU 3 and AEU 9. Different sub optimal and super optimal levels of the theoretical optimum of nutrients viz., N,P, K, Mg, Zn, B and Dolomite was kept as treatments for conducting these experiments in the two locations of AEU 9 and one location in AEU 3. Based on the corm yield data from these experiments, the actual optimum derived by conducting the NOP (Nutrient Omission Plot) and NLE (Nutrient Level Experiment) was N: P: K: Mg: Zn: B: Dolomite @ 140: 20: 225: 19.2: 4.2: 1.575: 1500 kg ha^{-1} for AEU 3 and 160:12.5:180: 19.2:6.3:1.975:1500 kg ha^{-1} for AEU 9 respectively and these experiments formed the basis for calculating the different nutrient use parameters for arriving at the grades of the customized fertilizer formulations.

Key words: Elephant foot yam, customized fertilizer formulations, nutrient omission experiment, nutrient level experiment, sub optimal level, super optimal level, corm yield

Introduction

Root and tuber crops are one of the most important staple foods in developing countries. The people depending upon these groups of crops are mostly poor, who in turn mainly rely on the high quantity of dietary energy supply for their existence. Among the tropical tuber crops, elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is valued as an important vegetable with high yield potential having good medicinal and nutraceutical properties. It is classified under the group of vegetables in India having a production of 659 MT from an area of 26,000 ha land (GOI, 2017). In Kerala, EFY is cultivated in an area of 7143 ha, mostly in the districts of Wayanad, Kollam, Pathanamthitta, Alappuzha, Kottayam and Thiruvananthapuram (Farm guide, 2018). Due to its economic value as well as medicinal properties, it is raised as a cash crop with good acceptance throughout the world. It is an annual herbaceous C3 diploid belonging to the family Araceae which in turn is regarded as a profitable and ideal intercrop for the plantations especially coconut gardens of Kerala. Elephant foot yam is a high nutrient demanding and nutrient responsive crop. Studies conducted on the fertilizer requirement of EFY in Kerala indicated its requirement as N, P_2O_5 and K_2O @ 100:50:150 kg ha^{-1} (Nair et al., 1990). Ravindran et al., (2006) reported an application rate of FYM @12.5 t ha^{-1} and NPK @ 25:30:33 kg ha^{-1} for EFY under intercropping in coconut gardens without affecting the soil fertility.

Being a high nutrient demanding crop due to its high biological efficiency, balanced fertilization is very important to this crop for realizing high yield as well as in protecting the soil ecosystem. Among the different nutrient management approaches, customizing the nutrient (major, secondary and micronutrients) requirement of crops with respect to specific agro ecological units (AEUs) based on the nutrient uptake of the crop and innate nutrient supplying capacity of the soil is the newest technology which can avoid the indiscriminate fertilizer use thereby increase the nutrient use efficiency (NUE), reduces the environmental pollution and ultimately sustains the net profit. In this regard, as part of the protocol in evolving the grades of the customized fertilizer (CF) formulations, arriving at the optimum nutrient requirement of the soil growing the crops is an inevitable component. As indicated, the theoretical optimum is a crude estimation based on the soil test data of the different nutrients of two different soil types viz., sandy and clayey/loamy as per Aiyer and Nair (1985) where the nutrient recommendation arrived is a percentage of the existing package of practices (PoP). From the theoretical optimum, the actual optimum is arrived by conducting nutrient omission plot (NOP) experiment in the case of major nutrients like N, P, K and nutrient level (NL) experiments for secondary and micro nutrients like Mg, Zn and B. The treatments for these two experiments were different levels (sub and super optimal) of the nutrients arrived as theoretical optimum based on the nutrient status of the soil as per weighted average method. Since the essential concept of customized fertilizers are region specific (as the soil chemical properties vary essentially under different agro ecological conditions) and crop specific, the present research work was confined to one of the important tuberous vegetables viz., elephant foot yam which is mostly grown in the laterite (Ultisols) (AEU9) and sandy plain soil (Entisols) (AEU3) types of Kerala.

Materials and Methods

The study locations viz., Onattukkara sandy plain (AEU 3) extends mainly to the two districts such as Alappuzha and Kollam covering 43 panchayats and laterite (AEU 9) covering the major six districts such as Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam and Ernakulam having 161 panchayats.

In the process of evolving the grades (percentage of nutrients) of the CF, we have evolved the theoretical optimum of the nutrient status of the soils of two AEUs through weighted average method. Based on the weighted average data of each soil parameter, the soil test based fertilizer recommendation for elephant foot yam for the two AEUs was evolved as per Aiyer and Nair (1985) for major nutrients (N, P, K) and soil critical level for secondary (Ca, Mg) and micronutrients (Zn, B) as per KAU (2012). The objective of conducting the NOP and NL experiments were to determine the actual optimum rate of application of these nutrients.

The theoretical optimum rate of nutrients arrived from the weighted average data was N : P : K : Mg : Zn : B : Dolomite @ 71 : 12.5 : 106.5 : 16 : 5.25 : 1.31 : 1000 for AEU 3 and 78 : 12.5 : 90 : 16 : 5.25 : 1.31 : 1000 kg ha^{-1} for AEU 9 respectively.

The treatment details of NOP experiment is given in Table 1.

As regards to N and K, five levels viz., N/K (omission of N and K), 0.75, opt, 1.5 and 2 fold of the recommended dose (theoretical optimum) of N/K as per weighted average soil data was taken. In the case of P, as the recommended rate was zero as per weighted average, a maintenance dose of 25 % (1/4) of PoP (Package of Practices) was taken as the optimum (P) and the super optimal 1 and 2 were 1.25 and 1.5 fold of theoretical optimum P. The farmers' practice based on the survey conducted was factomphos (N: P: K: S @ 20: 20: 0:13) @ 500 kg ha^{-1} along with muriate of potash (MOP) @ 750 kg ha^{-1} and urea @ 500 kg ha^{-1} in addition to FYM @ 25 t ha^{-1}. The PoP recommendation was NPK @ 100: 50: 150 kg ha^{-1} along with FYM @ 25 t ha^{-1} and there was an absolute control too. The time of application of the fertilizers containing these nutrients were as per the existing PoP of Kerala Agricultural University.

The treatment details of the NL experiment is presented in Table 2. The limiting nutrients viz., Ca, Mg, Zn and B

Table 1. Treatment details of Nutrient Omission Plot (NOP) experiment

Treat No.	Treatment Description	Notation	Rate of application
T1	Theoretical Optimum (T.O) based on weighted average (NPK)	NPK_{Opt}	Optimum rate of NPK, Ddolomite, Mg, Zn, B
T2	T.O-Nitrogen (N)	-N	No Nitrogen (N)
T3	T.O + Sub optimal N	N1	0.75 N
T4	T.O + Super optimal N-1	N2	1.5 N
T5	T.O + Super optimal N-2	N3	2N
T6	T.O -Phosphorus (P)	-P	No Phosphorus (P)
T7	T.O + Super optimal P-1	P1	1.25 P
T8	T.O + Super optimal P-2	P2	1.5 P
T9	T.O -Potassium (K)	-K	No Potassium (K)
T10	T.O + Sub optimal K	K1	0.75 K
T11	T.O + Super optimal K-1	K2	1.5 K
T12	T.O + Super optimal K-2	K3	2 K
T13	Farmers Practice	FP	FP
T14	Package of practices (PoP)	PoP	PoP
T15	Absolute control	AC	AC

Table 2. Treatment details of Nutrient Level (NL) experiment

Treat No.	Treatment Description	Notation	Rate of application
T1	Theoretical Optimum (T.O) based on weighted average (N, P, K, Mg, Zn, B)	Opt	Optimum rate of NPK, Dolomite, Mg, Zn and B
T2	T.O + Sub optimal Dolomite (D)	D1	0.5 D
T3	T.O + Super optimal Dolomite-1	D2	1.5 D
T4	T.O + Super optimal Dolomite-2	D3	2 D
T5	T.O + Sub optimal B	B1	0.5 B
T6	T.O + Super optimal B-1	B2	1.25 B
T7	T.O + Super optimal B-2	B3	1.5 B
T8	T.O -Dolomite + Optimal Magnesium(M)	M	M
T9	T.O -Dolomite + Sub Optimal Mg-1	M1	0.25 M
T10	T.O -Dolomite + Sub Optimal Mg-2	M2	0.5 M
T11	T.O -Dolomite + Super Optimal Mg	M3	1.5 M
T12	T.O + Mg (M2)-D (Opt)	M2-D	0.5 M-D
T13	T.O + Sub optimal Zinc (Zn)	Zn1	0.5 Zn
T14	T.O + Super optimal Zn-1	Zn2	1.5 Zn
T15	T.O + Super optimal Zn-2	Zn3	2 Zn

as per KSPB (2013) was taken for standardization under the NL experiment. For Ca and Mg, dolomite was chosen as the amendment as Susan John et al., (2013) reported dolomite as the best soil amendment for tuber crops in the Ultisols of Kerala. In the NL experiment, for standardization of dolomite and Zn, the sub optimal levels were half of optimum and the super optimal levels were 1.5 and 2 fold of the level of optimum. For Mg, there were two sub optimal levels viz., 0.25 and 0.5 fold of the optimum dose of Mg and the super optimal was 1.5 fold. For B, the sub optimal level was 0.5B and super optimal levels were 1.25B and 1.5B.

These experiments were conducted in three locations viz., two in AEU 9 and one in AEU 3 and were in the same sites too under coconut gardens of 8-30 years. These trials were conducted with EFY variety Gajendra and were laid out in randomized block design (RBD) with 15 treatments replicated twice. Each plot consisted of 25 plants and the plot size was 4.5 × 4.5 m accommodating 16 outer and nine inner plants. The most important parameter taken for arriving at the actual optimum of the nutrients under study from these experiments was corm yield. Here, the corm yield from the net plot comprising of nine plants were taken and was converted on per hectare basis.

Results and Discussions

The results of the two experiments viz., NOP and NL conducted at two locations of AEU9 viz., AEU 9(1) and AEU 9(2) and one location in AEU 3 for standardization of the actual optimum doses of nutrients viz., N,P, K, Mg, Zn, B and dolomite are presented below:

Corm yield under NOP experiment for major nutrients

In the first experiment, N was applied at five rates as minus N, optimum N, 0.75 fold N (sub optimal), 1.5 fold N (super optimal 1) and 2 fold N (super optimal 2) for AEU 3 and AEU 9. The corm yield data indicated 2N as significantly higher giving a corm yield of 45.95 t ha^{-1} in AEU 3. In AEU 9 (1), optimum N (33.61 t ha^{-1}) was on par with 1.5 N (38.74 t ha^{-1}) and 2N (45.18 t ha^{-1}). But in AEU 9 (2), 2N (43.88 t ha^{-1}) was on par with 1.5 N (36.01 t ha^{-1}). However, the average data of the two locations of AEU 9 indicated that 2N (45.00 t ha^{-1}) as significantly highest over other treatments. Hence, 2N (142 kg ha^{-1} for AEU 3 and 156 kg ha^{-1} for AEU 9 respectively) was taken as the optimum for the two AEUs. The better response in corm yield obtained (Kavitha and Sujatha, 2015) in the coconut growing areas which were deficient in nitrogen (30%) can be attributed to better response of EFY to the higher levels of N. Moreover, as N is one of the most important single factors limiting the production of the yam tuber (Aduayi and Okpon, 1980), application of this nutrient at the highest level might have resulted in higher tuber yield.

As regards to P, four levels of P as minus P, optimum P, 1.25 fold P (super optimal 1) and 1.5 fold P (super optimal 2) were taken where the theoretical optimum P was 0.25 % of the recommended dose (P @ 12.5 kg ha^{-1}). In AEU 3, 1.5 P resulted in significantly the highest corm yield (36.59 t ha^{-1}). In AEU 9, in both locations, minus P resulted in higher yield on par with the other higher levels. But the mean data over these two locations revealed optimum P (P @ 12.50 kg ha^{-1}) on par with other higher levels and hence in AEU 3, P @ 18.75 kg ha^{-1} and in AEU 9, optimum P @ 12.5 kg ha^{-1} was taken. Fernandes et al., (2015) indicated that, P application can increase the yield of marketable tubers in yams.

In the case of K, there were 5 levels as minus K, 0.75 fold K (sub optimal), optimal K, 1.5 fold K (super optimal 1) and 2 fold K (super optimal 2) of the theoretical optimum. Among the five levels, in AEU 3, 2K as K @ 212 kg ha^{-1} resulted in significantly the highest corm yield (46.41 t ha^{-1}). Moreover, in two locations of AEU 9, 2K (45.71 t ha^{-1}) resulted in significantly the highest corm yield. Hence, in both locations, 2K @ 212 kg ha^{-1} in AEU 3 and 180 kg ha^{-1} in AEU 9 was taken as the optimum. The significance of K in enhancing the productivity of tuber crops was reported by many researchers (McDole et al., 1987; Sharma and Arora, 1987; Tindall and Westermann, 1994). According to Susan John et al., (2010), K is the most significant nutrient for tropical tuber crops for enhancing tuber yield, tuber quality and maintaining soil available K status. Nair et al., (1990) found that, the fertilizer requirement of EFY is comparatively more among other tropical tuber crops and Venkatesan et al., (2014) reported that, corm yield can be increased by increasing the fertilizer levels. The corm yield data from the NOP experiment of the two locations of AEU 9 is presented in Table 3 and the

Table 3. Corm yield (t ha^{-1}) under NOP and NL experiments under two locations of AEU 9

Description	AEU 9(1)	AEU 9(2)	Description	AEU 9(1)	AEU 9(2)
Opt	33.61	27.02	OPT	37.28	31.00
-N	26.74	21.94	0.5 D	33.70	27.21
0.75N	29.93	23.30	1.5D	41.62	37.13
1.5N	38.74	36.01	2 D	45.36	40.73
2N	45.18	43.88	0.5 B	32.22	29.05
-P	27.91	24.43	1.25 B	33.27	33.71
1.25P	29.49	30.113	1.5 B	43.15	39.03
1.5P	33.09	31.67	M	37.97	37.23
-K	27.81	24.17	0.25 M	25.62	14.51
0.75K	31.63	25.57	0.5 M	26.11	18.28
1.5K	40.18	28.04	1.5 M	40.77	46.60
2K	47.01	43.73	Zn	29.28	27.19
FP	29.29	35.33	0.5 Zn	28.97	27.37
PoP	28.85	30.88	1.5 Zn	36.12	37.91
AC	20.35	28.36	2 Zn	39.42	33.54
SEm ±	3.92	3.68	SEm ±	1.80	4.94
(CD $p<0.05$)	11.89	11.17	(CD $p<0.05$)	5.45	5.00

corm yield data of AEU 3, mean of AEU 9 and mean of AEU 3 and 9 is depicted in Fig.1.

Corm yield under NL experiment for secondary and micronutrients

In the second experiment, the constraint nutrients typical for these two AEUs viz., Ca, Mg, B and Zn were standardized through a NL experiment using different levels of the nutrients in question as in the NOP experiment. Since Ca and Mg are deficient in these two AEUs, dolomite was recommended as the best soil amendment (Susan John et al., 2013). As regards to the corm yield under dolomite application in AEU 3 and 9,

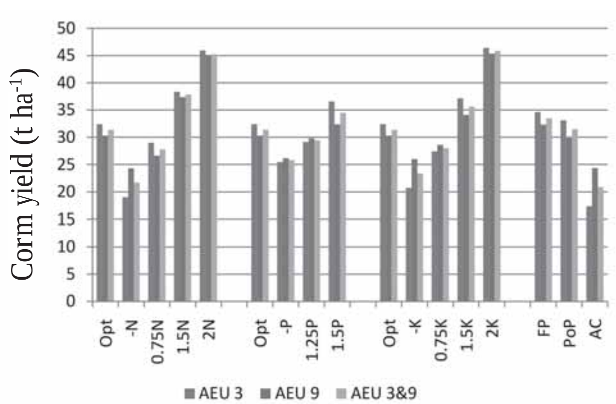

Fig. 1. Corm yield of AEU 3, AEU 9 and mean of AEU 3 & 9 under NOP experiment

2D was on par with 1.5D and hence in both AEUs, dolomite @ 1.5 t ha^{-1} was recommended as the optimum. Better response of EFY to dolomite can be justified as per the studies of Wissen et al., (2015) that, Ca was effective in enhancing tuber weight and hence tuber yield.

In the case of Mg, in both AEUs, 1.5 fold Mg was on par with optimum Mg (12.8 kg Mg), and hence, 1.5 fold Mg (Mg @ 19.2 kg ha^{-1}) was taken as the optimum. The result is in conformity with the reports of Talukder et al., (2009) that, the tuber yield in potato increased significantly with increasing rate of Mg up to 10 kg ha^{-1}. Susan John (2011) reported that, Mg deficiencies in crops are caused not only by inadequate exchangeable solution Mg but also by cation antagonisms in acid soils especially with respect to K.

In AEU 3, 2 fold Zn was on par with all levels except 0.5 fold Zn and hence Zn optimum (4.2 kg Zn) was taken as the optimum. In AEU 9, the mean data over the two locations indicated, 2 fold Zn is on par with 1.5 fold Zn and hence 1.5 fold Zn (6.3 kg Zn) was taken as the optimum. Hence, in AEU 3, Zn @ 4.2 kg ha^{-1} and in AEU 9, 1.5 fold Zn as 6.3 kg ha^{-1} has been taken as the optimum. Studies indicated that, Zn has a significant role in enzyme systems and is a team player with NPK in plant developmental processes (Sahota et al., 1982).

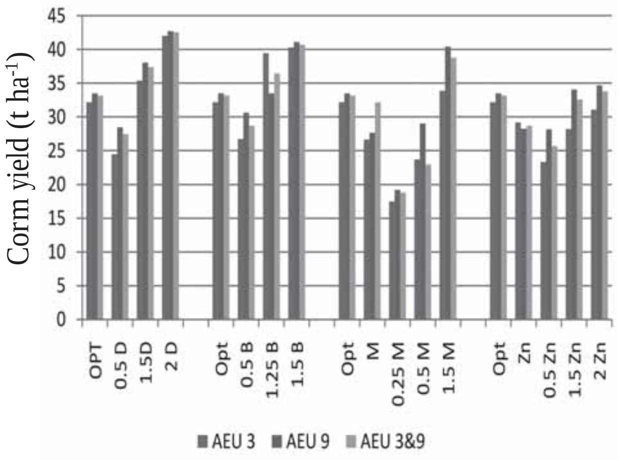

Fig. 2. Corm yield of AEU 3, AEU 9 and mean of AEU 3&9 under NL experiment

In AEU 3 and 9, B as 1.25 fold B and 1.5 fold B was found as optimum respectively which in turn was 15 and 18.75 kg borax having 1.575 and 1.975 kg B per ha respectively. Sahota et al., (1982) found that, trace elements like Zn and B can increase the tuber yield by increasing the tuber size and tuber number.

Based on the corm yield data of the two AEUs, the optimum nutrient rate of primary (N, P, K), secondary (Mg), micronutrients (Zn, B) and dolomite were standardized for the two AEU's as N: P: K: Mg: Zn: B: Dolomite @ 140: 20: 225: 19.2: 4.2: 1.575: 1500 kg ha^{-1} for AEU 3 and 160 :12.5: 180: 19.2: 6.3: 1.975:1500 kg ha^{-1} for AEU 9. The corm yield data of the two locations of AEU 9 is presented in Table 3 and the corm yield data of AEU 3, mean of AEU 9 and mean of AEU 3 and 9 from the NL experiment is depicted in Fig.2. The increased absorption and uptake and the resultant corm yield can be attributed to the favourable nutritional environment in the root zone of EFY crop created by the addition of manures and fertilizers (Mondal and Roy, 2001). The present finding corroborates to the reports of Sinhababu et al., (2013) that, in EFY, higher corm yield with full dose of fertilizer as $N:P_2O_5:K_2O$@ 80:60:80 kg ha^{-1} could be realized. Inclusion of dolomite in the present optimum nutrient dose can be attributed to the findings of Susan John et al., (2013) that, dolomite and gypsum are better with respect to improvement in soil acidity through increasing pH and exchangeable Ca and Mg content of the tuber crop growing soils of Kerala.

Conclusion

Among the different nutrient management approaches, customization of the required nutrients based on nutrient requirement of the crop and innate nutrient supplying ability of the soil has been found as appropriate for a crop like elephant foot yam. As the evolution of the grades of the customized fertilizers require systematic protocol including arriving at the actual optimum nutrient requirement for a specific crop for a specific soil, the experiments viz., nutrient omission plot and nutrient level experiments were conducted for elephant foot yam in the major tuber crops growing soils of Kerala viz., laterites (AEU 9) and sandy plain soils of Onattukara (AEU 3). Hence, based on the corm yield data of the two experiments conducted in three locations each could realize that, the actual requirement of all nutrients are distinctly more compared to the theoretical optimum fixed based on the weighted average data. The conduct of both NOP and NLE clearly revealed that, the theoretical optimum of both major, secondary and micronutrients taken based on soil test data cannot be a precise estimate as the nutrient application rate arrived at based on different levels including N, P, K omission treatments are found as drastically different with respect to each nutrient. When the theoretical optimum arrived based on weighted average soil data was N : P : K : Mg : Zn : B : Dolomite @ 71 : 12.5 : 106.5 : 16 : 5.25 : 1.31 : 1000 for AEU 3 and 78 : 12.5 : 90 : 16 : 5.25 : 1.31 : 1000 kg ha^{-1} for AEU 9, the actual optimum arrived for the two AEUs was N: P: K: Mg: Zn: B: Dolomite @ 140: 20: 225: 19.2: 4.2: 1.575: 1500 kg ha^{-1} for AEU 3 and 160 :12.5: 180: 19.2: 6.3: 1.975:1500 kg ha^{-1} for AEU 9. In addition to arriving at the actual optimum of nutrients, the data derived from the two experiments were used to compute parameters like nutrient requirement, total soil available nutrient, percent contribution from soil, nutrient uptake, innate nutrient supply from the soil and fertilizer use efficiency to calculate the quantity of nutrients to be supplied through the customized fertilizer mixtures.

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