



Development of Protocol for Custom Mixed Fertilizers for Elephant Foot Yam under Intercropping in Coconut Gardens of the Two Agro- Ecological Units of Kerala

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Abstract

Root and tubers are the third most important food crops constituting either the staple or subsidiary food for about one fifth of the world population. Elephant foot yam (EFY) (*Amorphophallus paeoniifolius* (Dennst).Nicolson) is a highly potential tropical tuber crop and an ideal intercrop for the coconut gardens of Kerala especially in Agro Ecological Unit (AEU) 9 (South central laterites) and AEU 3 (Onattukara sandy plain) having laterite and sandy soil types. This paper narrates the protocols designed for the development of nutrient mixtures comprising of major, secondary and micronutrients for EFY intercropped in coconut gardens known as 'custom mixed fertilizers'. It is a mixed multi nutrient carrier whose sources are from inorganic and organic origin which are formulated through specific systematic process of granulation and satisfies the nutritional demands of the crop, specific to agro ecology, soil type and plant need designed taking into account the farmers nutrient management strategy also. The present study for the formulation of the custom fertilizer for the two AEU's included the optimization of all required nutrients based on the weighted average of the soil data of the two AEU's comprising of 43 (AEU 3) and 161 (AEU 9) panchayats followed by validation of the optimum fixed through nutrient omission and nutrient level plot techniques for both major, secondary and micronutrients as field experiments in farmers plots and on station. Based on the survey on farmers' nutrient application strategy, tuber yield, plant nutrient contents, total plant uptake, pre and post soil test data, parameters like nutrient requirement, % contribution from soil, fertilizer use efficiency and nutrients to be applied through fertilizers were arrived. By fitting these parameters in soil test crop response and response curve approaches, the rate/ grades of component nutrients for the custom made fertilizers and their levels of application for the two AEU's were designed. The three grades designed were tried in two rates in five locations of the two AEU's with eight treatments (including package of practices and farmers' practice) replicated thrice in randomized block design.

Key words: *Amorphophallus paeoniifolius*, agro ecological units, tuber yield, nutrient requirement, fertilizer use efficiency, customized fertilizer, soil test crop response, response curve

Introduction

Elephant foot yam (EFY) is one of the most important tropical tuber crops having high nutrient demand

because of its very high yield potential to the tune of 30-70 t ha⁻¹. Studies indicated that, elephant foot yam is a fertilizer responsive crop that could produce profitable

yields under adequate fertilization (Biswanath et al. 2014) and hence provision of adequate nutrition is essential for better growth and tuber yield. Though the blanket recommendation of EFY is standardized as NPK @ 100:50:150 kg ha⁻¹ along with 25 t ha⁻¹ FYM, (Nair and Mohankumar, 1991) as there is no systematic fertilizer management strategy in place, there is wide spread occurrence of nutrient deficiencies especially that of secondary and micronutrients. Moreover, the most modern concept as regards to nutrient management is to evolve nutrient recommendations comprising of all essential nutrients specific to crops and soils especially which are significant for the crop and limiting in that particular soil. Since EFY is grown on a wider scale as intercrops in coconut gardens in agro ecological unit (AEU 3) (Onattukara sandy plain) and AEU 9 (south central laterites), research work has been carried out to design fertilizer mixtures (custom made fertilizers) containing major, secondary and micronutrients specific to EFY for the above two agro ecological units.

Hegde et al. (2007) reported that, at present, multi macro and micronutrient mixtures are found to facilitate the application of a wide range of plant nutrients to suit the specific requirements of the crops, soils and growth stages. 'Custom made fertilizers' emerged as a new idea of scientific research in the field of nutrient management specific to soils and crops. According to Fertilizer Control Order (FCO), these fertilizers are generally assumed to maximize crop yields while minimizing unwanted impacts on the environment and hence on human health. It is generally formulated based on a series of experiments to arrive at the nutrient optimum specific to soil and crop other than taking into account the consumer preference especially with respect to the application rates. Rakshit et al. (2012) indicated that, customized fertilizer (CF) manufacture basically involves mixing and crushing of fertilizers followed by steam injection, granulation, drying, sieving and cooling, so as to get a uniform product with every grain having the same nutrient composition. Since designed fertilizers specific to crops and regions are becoming popular, this paper narrates the protocols developed to formulate customized fertilizer mixtures for EFY intercropped in coconut gardens of the two agro ecological units of Kerala viz., AEU 3 and AEU 9.

Materials and Methods

The study area viz., AEU3 includes two districts such as Alappuzha and Kollam having 43 panchayats and AEU 9 covers six districts such as Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam and Ernakulam with 161 panchayats where EFY is an important commercial tuberous vegetable as intercrop in coconut gardens. The methodology for the development of CF involved the following steps.

Evolution of the weighted average of the soil chemical parameters and STBF rate for the two AEU's

For this, the crop and soil database of elephant foot yam growing regions was build up from the soil database of the independent panchayats of the whole State of Kerala available with the Kerala State Planning Board coordinated project on 'Soil based plant nutrient management plans for agro ecosystems of Kerala'. The weighted average of the soil test data of the comprising panchayats of the two AEU's was computed taking into account the average chemical parameters of each panchayat with respect to its area. The weighted average data of each soil chemical property was used to arrive at the soil test based fertilizer (STBF) rate for two agro ecological units as per Aiyer and Nair (1985) for major nutrients and soil critical level for secondary and micronutrients as per KAU (2012).

Nutrient omission plot experiments and nutrient level experiments to arrive at the optimum rate of application of nutrients for the two AEU's

In order to arrive at the optimum nutrient rate of major (N, P, K), secondary nutrients (Mg) and micronutrients (Zn, B), two separate experiments as nutrient omission plot experiment and nutrient level experiments with different levels of the nutrient in question were conducted in three locations viz., two in AEU 9 (farmer plot at Kozhencherry in Pathanamthitta district and one in on station at ICAR-CTCRI) and one in AEU 3 (farmer plot in Chettikulangara in Alapuzha district) during 2015-16. 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.

a. Nutrient omission plot experiment for major nutrients

In the case of N and K, in addition to the omission treatment (minus), one sub optimal ($\frac{3}{4}$ of the

recommended dose as per soil test) and two super optimal levels (1½ and 2 times of the recommended dose as per soil test) was taken. In the case of P, based on the soil test, as the recommended rate was zero, a maintenance dose of 25% of PoP (Package of Practices) was taken as the optimum and the super optimal 1 and 2 were ½ (0.5) and full dose of the PoP recommendation and the levels of nutrients viz., Mg, Zn, B and dolomite were kept optimum in both AEU's, for this experiment.

b. Nutrient level experiment for secondary and micronutrients

The secondary and micronutrients taken care were Ca, Mg, Zn and B as they were found limiting for these two soil types as evidenced from the project report of the Kerala State Planning Board (KSPB, 2013). For Ca and Mg, dolomite was chosen as the amendment as Susan John et al. (2013) already reported dolomite as the best soil amendment for tuber crops in the Ultisols of Kerala. Hence, for standardization of dolomite, Zn and B, the sub optimal levels was half of optimum and the super optimal levels were 1½ and 2 times the level of optimum. Since dolomite was given as a soil amendment and Mg is very significant for elephant foot yam, Mg dose also was standardized with two sub optimal levels viz., ¼ and ½ of the recommended dose of Mg and the super optimal was 1½ times of the recommended dose.

After planting the crop, the treatments were given through fertilizers as basal and top dressing at the recommended dose during specific time periods. Destructive sampling was done at peak vegetative growth stage of the crop around 6 MAP from inner plants. The fresh weight of the entire lamina and pseudostem of two plants per plot was recorded and 100g fresh weight of these samples was oven dried for dry matter and other chemical analyses. Harvesting was done at 10 MAP and tuber yield was recorded. The pre and post harvest soil samples also were analyzed for all the nutrients in question.

Arriving at the optimum nutrient rate of each nutrients for the two AEU's

Based on the tuber yield data of the two AEU's, the optimum nutrient rate of primary (N, P, K), secondary (Mg), micronutrients (Zn, B) and dolomite were standardized.

Understanding the nutrient application rate by EFY farmers of the two AEU's

A Survey was conducted to assess the general nutrient management strategy of EFY growing farmers of the two AEU's of Kerala to get an overview of the type of organic manures, chemical fertilizers, their rate and mode of application when EFY is grown under coconut as intercrops which in turn will help to decide on the rate of application of the CF developed in parity with farmers' application rate. A total of 72 farmers belonging to the different places of AEU 3 and 9 were interviewed for this purpose and the data obtained was tabulated in excel sheet and used in arriving at the level of application of the CF designed.

Arriving at the grades of the CF for the two AEU's

From the recorded observations, parameters like nutrient requirement (NR) (kg nutrient taken up per ton of tuber), soil available nutrient supply, percentage nutrient contribution from soil (CS %), soil nutrient supply (kg ha⁻¹), total plant nutrient uptake (kg ha⁻¹), nutrient to be taken from the fertilizer (kg ha⁻¹), fertilizer use efficiency (%) and fertilizer nutrient application requirement were computed. These parameters along with the survey results were used to design the fertilizer mixture grade which in turn contains nutrients viz., N and K @ 20 and 70% respectively and other nutrients in full based on the growth stage wise requirement of the crop and taking into account the manufacturing tips. The grades were designed based on soil test crop response (STCR) (for an yield target of 45 t ha⁻¹) and response curve (RC) approach for an application rate of 500 and 625 kg ha⁻¹ which was arrived based on the farmers' survey details.

Results and Discussion

Evolution of the weighted average of the soil chemical parameters of the two AEU's

The weighted average of the soil chemical parameters of the two AEU's is presented in Table 1.

The STBF rate evolved based on the above data of the two AEU's were as N, P, K, Mg, Zn, B, Dolomite @71:12.5:106.5:16: 5.25:1.31:1000 kg ha⁻¹ and 78:12.5:90:16:5.25:1.31:1000 kg ha⁻¹ for AEU 3 and AEU 9 respectively. Since EFY is aluminium tolerant and to some extent as dolomite is taking care of the Ca

requirement of the crop, Ca was not given separately and the Mg supply from dolomite is also considered in the process of standardizing the Mg rate.

Nutrient omission plot experiments and nutrient level experiment to arrive at the optimum rate of application of nutrients for the two AEU's

Tuber yield was taken as the first criteria to arrive at the optimum nutrient rate. The data generated from nutrient omission plot experiment and nutrient level experiment were used to arrive at the other parameters to design the grade of the custom made fertilizers.

a. Standardization of NPK (Nutrient omission plot experiment)

In the first experiment, N was applied at five rates as minus N, optimum N, 0.5 N (sub optimal), 1.5 N (super optimal 1) and 2N (super optimal 2) for AEU 3 and AEU 9. The tuber yield data indicated 2N as significantly highest giving a tuber yield of 45.954 t ha⁻¹ in AEU 3. In AEU 9, in location 1 (Kozhenchery), optimum N (33.612 t ha⁻¹) was on par with 1.5 N (38.739 t ha⁻¹) and 2N (45.179 t ha⁻¹). But in location 2 (Sreekariyam), 2N (43.877 t ha⁻¹) was on par with 1.5 N (36.012 t ha⁻¹). However, the average data of the two locations of AEU 9 indicated 2N (45.003 t ha⁻¹) as significantly highest than other treatments. Hence, 2N (142 kg ha⁻¹, 156 kg ha⁻¹ for AEU3 and AEU 9 respectively) was taken as the optimum for the two AEU's (Table 2). The better

response in tuber yield obtained with highest dose of N can be attributed to the reports of Kavitha and Sujatha (2015) that, coconut growing areas were more deficient in nitrogen (30%) and this might have resulted in better response to the applied higher levels of N. Moreover, as N being one of the most important single factors limiting the production of the yam tuber (Aduayi and Okpon 1980), application of this nutrient at higher level might have resulted in higher tuber yield.

As regards to P, four levels of P as minus P, optimum P, 1.25 P (super optimal 1) and 1.5 P (super optimal 2) were taken where the optimum P was 0.25 P (P @ 12.5 kg ha⁻¹). In AEU 3, 1.5 P recorded significantly the highest tuber yield (36.597 t ha⁻¹). In AEU 9, in both locations, minus P recorded yield on par with the other higher levels. But the mean data over these two locations revealed optimum P (P @ 12.5 kg ha⁻¹) as 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 (Table 4). The report (Fernandes et al. 2015) on P fertilization indicates that, P application can increase the yield of marketable tubers.

In the case of K, there were 5 levels as minus K, 0.75 K (sub optimal), optimal K, 1.5 K (super optimal 1) and 2K (super optimal 2). Among the five levels, in AEU 3, 2K as K @ 212 kg ha⁻¹ gave significantly the highest tuber yield (46.405 t ha⁻¹). In AEU 9, in location 1 (Kozhencherry), 2K (47.005 t ha⁻¹) was on par with 1.5 K (40.183 t ha⁻¹). In location 2 (Sreekariyam), 2K was significantly the highest with a tuber yield of 43.732 t ha⁻¹. The mean over two locations of AEU 9 showed 2K (45.714 t ha⁻¹) as significantly the highest in tuber 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 (Table 4). 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). Kabeerathumma et al. (1987) studied the N, P and K utilization pattern of elephant foot yam during different growth stages of the crop and found a progressive increase in the uptake of these nutrients with increase in the age of the crop. 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.

Table 1. Weighted average of the nutrient status of the two AEU's

Sl. No	Parameters	AEU 3	AEU 9
1	pH	5.7	5.5
2	Electrical conductivity (dS m ⁻¹)	0.29	0.28
3	Organic carbon (%)	0.937	1.386
4	Available P (kg ha ⁻¹)	60.47	64.6
5	Exchangeable K(kg ha ⁻¹)	209	271
6	Exchangeable Ca (meq 100g ⁻¹)	0.364	1.85
7	Exchangeable Mg (meq 100g ⁻¹)	0.307	0.875
8	Available S (ppm)	4.68	20.2
9	Available Zn (ppm)	3.74	5.3
10	Available Cu(ppm)	1.76	3.43
11	Available Fe (ppm)	99	60.83
12	Available Mn (ppm)	18.7	35.02
13	Available B (ppm)	0.683	0.78

Table 2. Tuber yield ($t\ ha^{-1}$) under different treatments of nutrient omission plot experiment

Treat	Description	AEU 3 (Chettikulangara)	AEU 9 (Kozhenchery)	AEU 9 (Sreekariyam)	Mean
T1	Opt	32.406	33.612	27.022	31.013
T2	N0	19.013	26.740	21.936	22.563
T3	0.5N	28.971	29.934	23.301	27.402
T4	1.5N	38.366	38.739	36.012	37.706
T5	2N	45.954	45.179	43.877	45.003
T6	P0	25.462	27.910	24.432	25.935
T7	1.25P	29.161	29.485	30.113	29.586
T8	1.5P	36.597	33.085	31.670	33.784
T9	K0	20.742	27.814	24.168	24.241
T10	0.75K	27.395	31.629	25.566	28.197
T11	1.5K	37.141	40.183	28.040	35.121
T12	2K	46.405	47.005	43.732	45.714
T13	FP*	34.660	29.291	35.329	33.093
T14	POP**	33.127	28.848	30.875	30.950
T15	AC	17.341	20.346	28.363	22.017
CD(0.05)		3.39	11.89	11.17	5.28

*FP: Farmers practice ** POP: Package of practices

b. Standardization of Ca, Mg, B and Zn (Nutrient level experiment)

In the second experiment, the constraint nutrients typical for these two AEU's viz., Ca, Mg, B and Zn were standardized through nutrient level experiment as in the previous experiment using different levels of the nutrients in question. Since Ca and Mg are deficient in these two AEU's, dolomite was recommended as the best soil amendment (Susan John et al. 2013). In order to standardize dolomite, four levels of dolomite viz., 0.5 D, opt D, 1.5 D and 2D were applied (Opt D @ $1t\ ha^{-1}$). Similarly for Mg, four levels viz., 0.25 Mg, 0.5 Mg, Opt Mg, 1.5 Mg and for Zn, four levels viz., 0.5 Zn, Opt Zn, 1.5 Zn and 2 Zn were applied. In the case of B, four levels of B as 0.5B, optimum B, 1.5 B and 2B were given as treatments in the two AEU's.

As regards to the tuber yield under dolomite, in AEU 3, 2D ($42.029\ t\ ha^{-1}$) was on par with 1.5D ($35.397\ t\ ha^{-1}$). In AEU 9, location 1, 2D ($45.356\ t\ ha^{-1}$) was on par with 1.5D ($41.621\ t\ ha^{-1}$) and in location 2, 2D was on par with 1.5 D ($37.134\ t\ ha^{-1}$) and opt D ($31.003\ t\ ha^{-1}$). The mean data over two locations of AEU 9 showed 2D ($42.704\ t\ ha^{-1}$) on par with 1.5 D ($38.051\ t\ ha^{-1}$) (Fig.1). Hence, in both AEU's, dolomite @ $1.5\ t\ ha^{-1}$ was recommended as the optimum. The good response with 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 AEU 3, 1.5 Mg ($33.887\ t\ ha^{-1}$) was on par with optimum Mg ($32.176\ t\ ha^{-1}$). In AEU 9, in both locations, 1.5 Mg was on par with opt Mg. The mean data over the two locations indicated 1.5 Mg as significantly highest than other levels (Fig.2). Hence, in both locations, 1.5 Mg (Mg @ $24\ kg\ ha^{-1}$) 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 $10\ kg\ ha^{-1}$.

In AEU 3, among the four levels of Zn, 2Zn ($31.081\ t\ ha^{-1}$) was on par with 1.5 Zn ($28.196\ t\ ha^{-1}$). In AEU 9, location 1, 2Zn ($39.419\ t\ ha^{-1}$) was on par with 1.5 Zn ($36.115\ t\ ha^{-1}$) and in location 2, 0.5 Zn was on par with all other levels. The mean data over the two locations indicated, optimum Zn as on par with the other higher levels. Hence in AEU 3, 1.5 Zn as Zn @ $7.88\ kg\ ha^{-1}$ and in AEU 9, Zn @ $2.63\ kg\ ha^{-1}$ has been taken as the optimum (Fig.3). Studies indicated that, Zn has a significant role in enzyme systems and is a team player with NPK in many plant development processes (Sahota et al. 1982).

In the case of B, in AEU 3, B at the optimum rate was on par with the other two higher levels. In AEU 9,

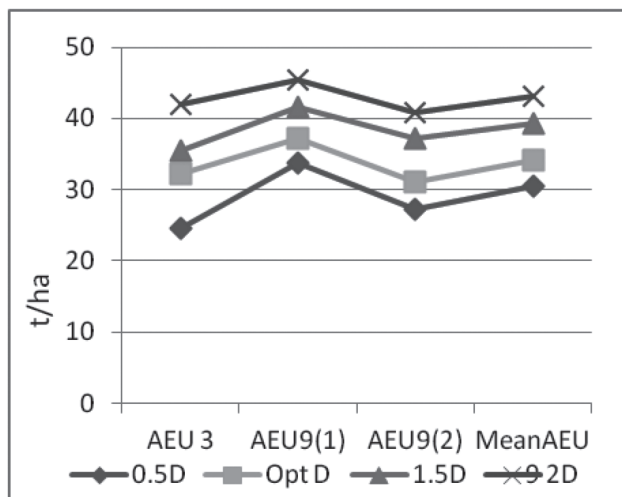


Fig.1. Effect of levels of dolomite on tuber yield of elephant foot yam

(Mg), micronutrients (Zn, B) and dolomite were standardized for the two AEU's as N: P: K: MgSO₄: borax: ZnSO₄: Dolomite:@ 150: 20 : 225: 120:12.5:10:1500 kg ha⁻¹ for AEU 3 and 120 :12.5: 200: 120: 12.5: 20 :1500 kg ha⁻¹ for AEU 9.

Understanding the nutrient application rate by EFY farmers of the two AEU's

The farmers' survey indicated the general application rate was as factomphos containing NPKS @ 20:20:0:15 @ 500 kg ha⁻¹, MOP @ 750 kg ha⁻¹ and urea @ 500 kg ha⁻¹ along with farm yard manure @ 25 t ha⁻¹. It is also known that, progressive farmers are applying 15 (750 kg) bags of chemical fertilizers and normal farmers are

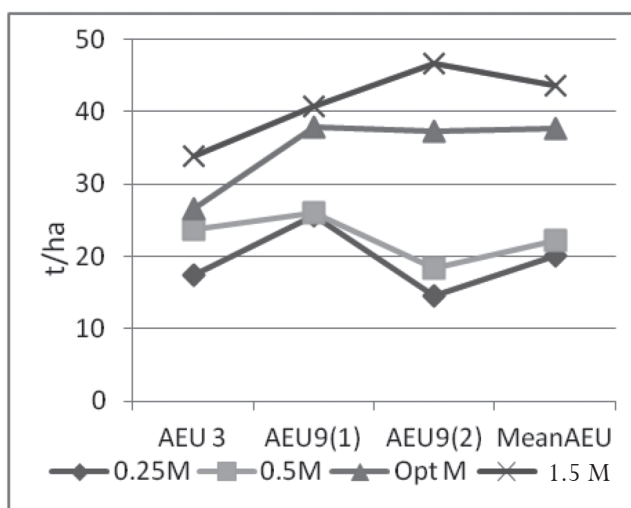


Fig.2. Effect of levels of magnesium on tuber yield of elephant foot yam

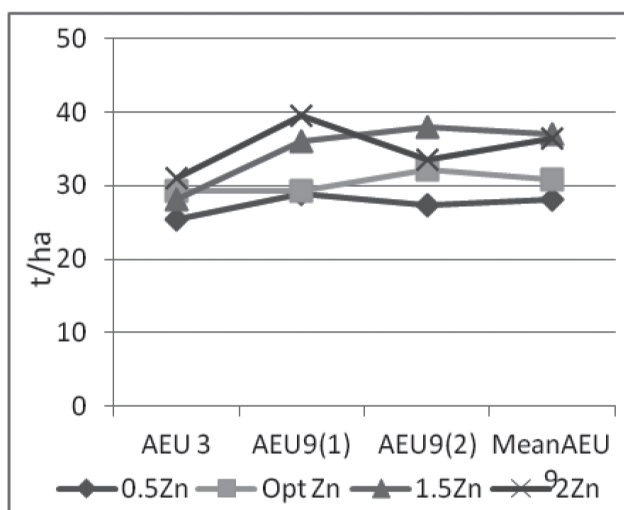


Fig.3. Effect of levels of zinc on tuber yield of elephant foot yam

location 1, 1.5 B recorded the highest tuber yield (43.269 t ha⁻¹) which was on par with 2B (40.154 t ha⁻¹) and optimum B (37.276 t ha⁻¹). In location 2, 2B (39.032 t ha⁻¹) was on par with 1.5 B (37.705 t ha⁻¹) and optimum B (31.003 t ha⁻¹). The average data of the two locations showed optimum B was on par with 1.5B and 2B. Hence, in both AEU's, optimum B (B @ 1.31 kg ha⁻¹) was taken as the optimum rate (Fig.4). 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.

Arriving at the optimum rate of application of nutrients for the two AEU's

Based on the tuber yield data of the two AEU's, the optimum nutrient rate of primary (N,P, K), secondary

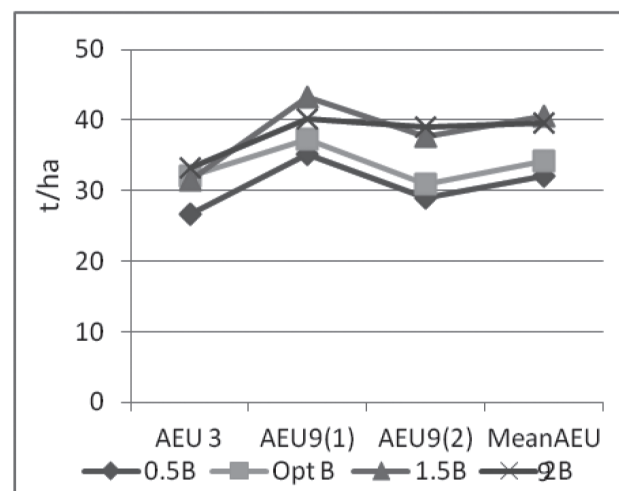


Fig.4. Effect of levels of boron on tuber yield of elephant foot yam

going for 10 (500 kg) bags of chemical fertilizers. Hence, the rate of application of the designed custom made fertilizer was fixed as 10- 15 bags ha⁻¹ (500-750 kg ha⁻¹).

Arriving at the grades of the CF for the two AEU's

The grades of the fertilizer mixture for the two AEU's were arrived using soil test crop response (STCR) and response curve (RC) approaches.

a. Soil test crop response (STCR) approach

The parameters computed to arrive at the grade of the fertilizer mixture included nutrient requirement (NR), nutrient uptake, total soil nutrient availability, percentage contribution from soil, fertilizer nutrient to be applied and fertilizer use efficiency. The NR (kg nutrient taken up for every ton of tuber) for both the AEU's were arrived as N, P, K @ 3.68, 0.7 and 4.47 kg. Byju et al. (2016) reported values as 4-4.29, 0.7-0.76, 7-7.63 kg N,P, K respectively for yield target ranging from 10-70 t/ha. In this study, the nutrient uptake calculated for an yield target of 45 t ha⁻¹ was 166 kg N, 32 kg P and 201 kg K ha⁻¹. According to Byju et al. (2016), the NPK uptake for an yield target of 45 t ha⁻¹ was reported as 179, 31, 318 kg ha⁻¹. The total soil nutrient availability inclusive of soil per se, manures and fertilizers were N, P, K @ 200,61, 209 for AEU3 and 200, 65, 271 kg ha⁻¹ for AEU 9. Of this, the percentage contribution from soil was 55.6, 33, 44.3% and 32.8,33 and 48.5% for AEU 3 and AEU 9 respectively. This was worked out as N, P, K @ 111, 20, 93 and 66, 21 and 131 kg ha⁻¹ for AEU3 and AEU 9 respectively as the soil nutrient supply. Byju et al. (2016) reported values as 94.16, 17.52 and 154.66 kg ha⁻¹ as indigenous NPK supply from the soil. In order to meet the NPK uptake for the yield target of 45 t ha⁻¹, the balance quantity of NPK @ 54, 11, 109 and 100, 10, 70 kg ha⁻¹ needs to be supplied by the fertilizers. Being the fertilizer use efficiency calculated as 27.1, 48.5, 90 and 54, 40, 48 % with respect to AEU3 and AEU 9, the fertilizer N, P₂O₅, K₂O requirement was arrived as 201,54, 145 and 185,58, 174 kg ha⁻¹ for AEU 3 and AEU 9 respectively. The fertilizer use efficiency as reported by Byju et al. (2016) was 32.35, 15.20 and 34.42% respectively. The grades of N, P₂O₅, K₂O of the CF for the two AEU's was developed with grades as 40, 54,102 and 37, 58, 122 for AEU3 and AEU 9 respectively taking into account the fact that, the CF needs to contain only 20% N and 70% K. For an application rate of 500

kg ha⁻¹ of the above CF's, the grades of N, P₂O₅ and K₂O were arrived as 8:11:21 for AEU 3 and 7:12:24 for AEU 9.

In the case of secondary and micronutrients, the optimum evolved as Mg, Zn and B @19.2, 4.2, 1.575 and 19.2, 6.3, 1.969 kg ha⁻¹ respectively were taken for AEU 3 and AEU 9 for arriving at the nutrient grade of the CF. Hence, the grades of Mg, Zn and B for the CF for AEU 3 and AEU 9 were fixed as 3.84, 0.84, 0.3 and 2.5, 1.25, 0.4% respectively taking into account the CF developed has to be applied @500 kg ha⁻¹. The final grade of CF (application rate of 500 kg ha⁻¹) for EFY intercropped in coconut gardens based on STCR approach for an yield target of 45 t ha⁻¹ was N: P₂O₅: K₂O: Mg: Zn: B as 8:11:21:3.5:1:0.3 for AEU 3 and 7:12:24:2.5:1.3:0.4 for AEU 9.

The technical and scientific expertise of Tata Chemicals (Centre for Agri solutions), Aligarh, Uttar Pradesh who are the pioneers in the development of customized fertilizers was utilized for arriving at the grades of the CF for the present study.

b. Response curve (RC) Approach

In the case of RC approach, the optimum nutrient rate evolved for the major, secondary and micronutrients from the nutrient omission and nutrient level plot experiments were utilized. In the response curve approach, the optimum for each of the nutrients were arrived at by plotting the response curve (levels of each nutrient versus tuber yield) and the optimum for N, P₂O₅, K, Mg, Zn and B for AEU 3 was arrived as 142,12.5,213,19.2,4.2,1.6 kg ha⁻¹ and 156, 12.5, 180, 19.2, 6.3 and 2 kg ha⁻¹ for AEU 9 respectively. Based on these, the grades of the component nutrients in the CF was evolved with 20% N, full P and 70% K and other nutrients full for an application rate of 500 kg ha⁻¹ as N, P₂O₅, K₂O, Mg, Zn, B @ 6:3: 30: 3.5: 0.8: 0.3% respectively for AEU 3 and for AEU 9, the grades were 7: 3: 25: 4: 1.25: 0.4%. In arriving at the four different grades of the CF for AEU3 and AEU 9 based on STCR and RC approach, the manufacturing tips for better granulation of the product like N:P ratio, percentage of steam and filler, type of P fertilizer, diammonium phosphate (DAP): triple super phosphate (TSP) ratio, percentage share of K fertilizer are taken into consideration.

Byju et al. (2016) based on QUEFTS model developed CF for EFY with grade as N: P: K: Mg: Zn: B for the three districts of Kerala viz., Malappuram, Wyanad and Ernakulam for an application rate of 650 kg ha⁻¹ as 12: 4: 18:3:0.4:0.2.

As the CF contained 20%N and 70% K, the rest of 80% N and 30% K needs to be applied as top dressing in the form of urea and MOP. Based on the grades arrived for the two AEU's as per STCR and RC approaches, three grades of CF as CF1 (STCR AEU 3), CF 2 (STCR AEU 9), CF3 (RC AEU 9) were formulated and they were applied in two rates as 500 and 625 kg ha⁻¹. To test the effect of these designed CF grades, field experiments were conducted during 2016-17 in three locations in AEU 9 (one location in Elamad, Kollam district, Kerala), one in Chullimannoor, Thiruvananthapuram district, Kerala) including on-station at ICAR-CTCRI, and one location in AEU 3 (Chettikulangara-Kayamkulam, Alapuzha district, Kerala) with 8 treatments including PoP (mostly straight NPK fertilizers as NPK @100:50:150 kg ha⁻¹) and farmer's practice replicated thrice in RBD and it is found that the three customized fertilizer formulations behaved on par at an application rate of 625 kg ha⁻¹.

Conclusion

Though the concept of designer fertilizers /customized fertilizers specific to crops and soils is a new concept, the experience with many crops like potato, sugar cane, wheat, maize, onion in different agro ecological zones of the country indicated it as a holistic solution for the present imbalanced and improper nutrient management strategies. As the basic philosophy in the development of custom made fertilizers involve pro active soil and plant tissue testing, inclusion of all the required nutrients specific to soil and crop in the required proportion and involvement of advanced scientific principle in the development of the fertilizer, it will definitely improve crop and soil productivity, produce quality, increase profit with better nutrient use efficiency. Hence, the present effort in the development of the designer fertilizer for EFY intercropped in coconut gardens of Kerala can help in meeting the above crop management benefits compared to the existing nutrient management practices.

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