Soil test crop response based integrated plant nutrition system for Ashwagandha (*Withania somnifera* L. Dunal) on Inceptisols

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Abstract
To elucidate the relationship between soil tests and response of ashwagandha to applied fertilizers under Integrated Plant Nutrition System (STCR-IPNS), a field experiment was conducted on Vertic Ustropept soils of Tamil Nadu (Southern India) during 2008-09 following Ramamoorthy's Inductive cum targeted yield model. Using the data on dry root yield, initial soil test values on available NPK, doses of fertilizers and farm yard manure (FYM) applied and NPK uptake, the basic parameters *viz.,* nutrient requirement, contribution from soil, fertilizers and FYM were computed. It was found that 77.6, 31.7 and 113.3 kg of N, P_2O_5 and K_2O respectively were required for producing one tonne dry root of ashwagandha. The percent contribution of nutrients from soil, fertilizer and FYM were 19.03, 31.30 and 23.14 for N; 20.26, 17.30 and 6.38 for P_2O_5; 11.08, 62.53 and 30.39 for K_2O respectively. Making use of these basic parameters, fertilizer prescription equations were developed for ashwagandha (*var*. JA 20) and an estimate of fertilizer doses formulated for a range of soil test values and desired yield targets under NPK alone and IPNS (NPK plus FYM).

Key Words
STCR-IPNS, Inceptisol, ashwagandha, fertilizer prescription, targeted yield

Introduction
Owing to current demand in the global market, cultivation of medicinal plants *viz.,* ashwagandha (*Withania somnifera* (L.) Dunal), also known as "Indian Ginseng", is gaining momentum in India. This has necessitated research to enhance its production potential to meet anticipated requirement through appropriate technologies. As fertilization practices would improve yield levels of ashwagandha, it is better to adopt an Integrated Plant Nutrition System (IPNS) based on soil fertility and crop requirement to ensure balanced fertilization. This is possible through use of Inductive cum Targeted yield model (Ramamoorthy *et al*., 1967) and hence this study was done on ashwagandha as a pioneer work.

Methods
A field experiment with ashwagandha was conducted during 2008-09 on Vertic Ustropept at TNAU farm, Coimbatore, Tamil Nadu (Southern India). The soil of the experimental field was mixed black calcareous, clay in texture with pH 8.42, EC 0.24 dS/m and cation exchange capacity of 23.1c mol (p+)/kg.The initial soil available nutrient status of alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K were 201, 21.5 and 570 kg/ha, respectively. The P and K fixing capacities of the soil were 90 and 100 kg/ha, respectively. By adopting the technique of inductive methodology developed by Ramamoorthy *et al.* (1967), variation in soil fertility was created by dividing the experimental field into three equal strips, which were fertilized with $N_0P_0K_0$ (strip I), $N_1P_1K_1$ (strip II)and $N_2P_2K_2$ (strip III) levels and a crop of fodder maize (*var* CO 1) was grown.

After the harvest of maize crop, each strip was divided into 24 plots and pre sowing soil samples were collected from each plot and analysed for alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al*., 1954) and NH_4OAc-K (Standford and English, 1949). The experiment was laid out in a fractional factorial design comprising twenty four treatments with four levels of N (0, 40, 80 and 120 kg/ha), four levels of P_2O_5 (0, 40, 80 and 120 kg/ha), four levels of K_2O (0, 20, 40 and 60 kg/ha) and three levels of FYM (0, 6.25 and 12.5 t/ha). The IPNS treatments *viz.,* NPK alone, NPK+ FYM @ 6.25 t/ha, NPK+ FYM @12.5 t/ha were superimposed across the strips. The 21 fertilizer treatments and three controls were randomized in such a way that all the 24 treatments were present in all the three strips in either direction. Fertilizer containing P_2O_5, K_2O, and FYM were applied as a basal treatment while fertilizer N was applied in two equal splits *i.e*., basal and 30 days after transplanting. The crop was grown to maturity and the fresh and dry root yields were recorded. From each plot, plant and root samples were collected, processed and analyzed for N (Humphries, 1956), P and K contents (Jackson, 1973). Using the dry matter yield, the uptake values were computed.

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The basic parameters *viz*., nutrient requirement (NR), contribution of nutrients from soil (Cs) and fertilizers (Cf) were calculated by Ramamoorthy *et al*. (1967) and FYM (Cfym) was estimated as described by Santhi *et al*. (2002) from the data on nutrient uptake, crop yield, initial soil available nutrients and fertilizer/FYM doses applied. These parameters were used for developing fertilizer prescription equations for deriving fertilizer doses and the soil test based fertilizer recommendations were prescribed for desired yield target of ashwagandha under NPK alone as well as IPNS (NPK plus FYM).

Results

Soil available nutrients and root yield

The range and mean values of root yield of ashwagandha and soil available nutrients of treated and control plots are furnished in Table 1. In the NPK treated plots (plots that received either NPK alone or NPK plus FYM), $KMnO_4$-N increased from 176 kg/ha in strip I to 270 kg/ha in strip III with a mean value of 227 kg/ha. The Olsen-P ranged from 16.5 kg/ha in strip I to 50.4 kg/ha in strip III with a mean value of 33.7 kg/ha, while the NH_4OAc-K status varied from 535 kg/ha in strip I to 635 kg/ha in strip III with a mean value of 584 kg/ha.

Table 1. Effect of treatments on available nutrients in pre sowing surface soil and dry root yield of ashwagandha.

Parameters	NPK treated plot		Control plot	
	Range	Mean	Range	Mean
$KMnO_4$ –N (kg/ha)	176 - 270	227	176 - 267	226
Olsen–P (kg/ha)	16.5 - 50.4	33.7	22.5 - 50.4	36.2
NH_4OAc-K (kg/ha)	535 - 635	584	535 - 613	574
Dry root yield (t/ha)	0.561 - 0.995	0.873	0.418 - 0.854	0.666

In the overall control plot of three fertility gradients (Table 1), the $KMnO_4$-N ranged from 176 to 267 kg/ha with a mean of 226 kg/ha, Olsen-P status ranged from 22.5 to 50.4 kg/ha with a mean value of 36.2 kg/ha, and the NH_4OAc-K status varied from 535 to 613 kg/ha with a mean value of 574 kg/ha. In the NPK treated plots (plots that received either NPK alone or NPK plus FYM), the dry root yield of ashwagandha ranged from 0.561 to 0.995 t/ha with a mean value of 0.873 t/ha. In the overall control plots, the yield ranged from 0.418 to 0.854 t/ha with a mean value of 0.666 t/ha.The above data clearly indicate the existence of operational range of soil test values for available N, P and K status and root yield of treated and control plots, which is a prerequisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets.

Basic parameters

The basic data *viz*., nutrient requirement for producing one tonne dry root yield of ashwagandha, percent contribution of nutrients from soil (Cs), fertilizer (Cf) and FYM (Cfym) have been calculated and furnished in Table 2. These basic parameters were used for developing the fertilizer prescription equations under NPK alone and IPNS. The nutrient requirement of N, P_2O_5 and K_2O were 77.6, 31.7 and 113.3 kg t^{-1} of dry root respectively. The percent contribution of nutrients from soil and fertilizers were found to be 19.03 and 31.30 for N, 20.26 and 17.30 for P_2O_5 and 11.08 and 62.53 for K_2O. Similarly the percent contribution of N, P_2O_5 and K_2O from FYM was 23.14, 6.38 and 30.39 respectively.

Table 2. Nutrient requirement, percent contribution of nutrients from soil, fertilizer and FYM for ashwagandha.

Parameters	Basic data		
	N	P_2O_5	K_20
Nutrient requirement (kg/t)	77.6	31.7	113.3
Per cent contribution from soil (Cs)	19.03	20.26	11.08
Per cent contribution from fertilizers (Cf)	31.30	17.30	62.53
Per cent contribution from FYM (Cfym)	23.14	6.38	30.39

The estimated Cf clearly revealed the fact that the magnitude of contribution by fertilizer K_2O was 3.6 times higher than P_2O_5 and twice as that of N. With regard to N and K_2O, comparatively more contribution was recorded from fertilizers than from the soil. However, in the case of P_2O_5, the contribution was more from soil than from fertilizer. Split application of N at the critical stages of crop growth would have resulted in better utilization of applied N, which was also indicated by the relatively higher response ratio recorded for fertilizer N than P_2O_5. The results observed in the present study corroborated with the findings of Panchabhai *et al*. (2005) for ashwagandha. With regard to K_2O, comparatively lower Cs was recorded which might be due to the preferential nature of ashwagandha towards the applied K_2O than the native K_2O. A

similar trend for all the three basic parameters was observed for cumin in Rajasthan (Muralidharudu *et al.,* 2007).

Fertilizer Prescription Equations under IPNS for desired yield target
Soil test based fertilizer prescription equations for desired yield target of ashwagandha were formulated using the basic parameters and are furnished below:

NPK Alone
FN = 247.7 T - 0.61 SN
FP_2O_5 = 183.3 T - 2.68 SP
FK_2O = 181.2 T - 0.21 SK

NPK + FYM
FN = 247.7 T - 0.61 SN - 0.74 ON
FP_2O_5 = 183.3 T - 2.68 SP – 0.84 OP
FK_2O = 181.2 T - 0.21 SK – 0.59 OK

where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg/ha, respectively; T is the yield target in t/ha; SN, SP and SK respectively are alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg/ha and ON, OP and OK are the quantities of N, P and K supplied through FYM in kg/ha.

An estimate of fertilizer doses was prepared based on these equations for a range of soil test values and for yield target of 0.9 t/ha dry root of ashwagandha. For achieving this target with soil test values of 200:20:500 kg/ha of $KMnO_4$-N, Olsen-P and NH_4OAc-K, the fertilizer N, P_2O_5 and K_2O doses required were 101, 111 and 56 kg/ha, respectively. When FYM (33 percent moisture, 0.65, 0.35 and 0.60 per cent of N, P and K respectively) @ 12.5 t/ha was applied along with NPK, the required fertilizer N, P_2O_5 and K_2O doses were 61, 87 and 26 kg/ha, respectively. Under IPNS, the contribution of nutrients in terms of fertilizer N, P_2O_5 and K_2O were 40, 24 and 30 kg/ha respectively for NPK plus FYM @12.5 t/ha. These quantities of nutrients can be subtracted from the recommended doses of fertilizers.

Table 3. Estimates of soil test based fertilizer recommendation for 0. 9 t/ha dry root yield target of ashwagandha (kg/ha).

Soil test values (kg/ha)			Fertilizer doses (kg/ha) under NPK alone			Fertilizer doses (kg/ha) under NPK+ FYM @ 12.5 t/ha		
SN	SP	SK	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
200	10	350	101	138	88	61	114	58
220	14	400	89	127	78	49	103	48
240	18	450	77	117	67	37	93	37
260	20	500	65	111	56	25	87	26

Conclusion
In the present study, the integrated plant nutrition system based on soil test crop response correlation studies was developed for ashwagandha on Vertic Ustropept soil of Tamil Nadu (Southern India) taking into account the nutrient requirement, contribution of NPK from the internal and external nutrient sources *viz.,* soil, fertilizer and FYM. This envisages a balanced supply of nutrients in an integrated manner through IPNS for the desired yield target of ashwagandha.

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