

Full Length Research Paper

Ashwagandha (*Withania somnifera* L. Dunal) crop as affected by the application of farm yard manure (FYM) and inorganic phosphorus in typic Torripsamment of Hisar

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The vegetative parameters of ashwagandha (viz. plant height, number of primary branches, plant spread and dry weight of shoot) were enhanced significantly with the application of 12.5 mg P₂O₅ kg⁻¹ soil, whereas; dry weight of roots was enhanced up to the application level of 25 mg P₂O₅ kg⁻¹ soil. FYM at the rate of 12.5 t ha⁻¹ in combination with 12.5 mg P₂O₅ kg⁻¹ soil significantly improved all the vegetative parameters, whereas, FYM at the rate of 12.5 t ha⁻¹ in combination with 25 mg P₂O₅ kg⁻¹ soil significantly enhanced the dry weight of the roots. The alkaloids yield (mg pot⁻¹) in ashwagandha roots increased significantly with the application of 25 mg P₂O₅ kg⁻¹ soil. The application of FYM at the rate of 12.5 t ha⁻¹ improved the alkaloids yield (mg pot⁻¹) but the significantly highest yield of total alkaloids (mg pot⁻¹) was found in the treatment combination of 12.5 t FYM ha⁻¹ + inorganic-P at the rate of 25 mg P₂O₅ kg⁻¹ soil as compared with other eleven treatments. Nutrients (NPK) uptake by ashwagandha shoot increased significantly with the application level of 12.5 mg P₂O₅ kg⁻¹ soil over control whereas in case of ashwagandha roots, the increase in nutrients uptake at the level of 25 mg P₂O₅ kg⁻¹ soil over control. Application of FYM at the rate of 12.5 t ha⁻¹ + 12.5 mg P₂O₅ kg⁻¹ soil was the best treatment combination for ashwagandha roots in terms of nutrients uptake. Application of fertilizer-P significantly improved the status of organic carbon, Available-P in post harvest soil but decreased the Available-N, Available-K and DTPA extractable micronutrients (Fe, Cu, Zn and Mn) up to the level of 25 mg P₂O₅ kg⁻¹ soil. FYM at the rate of 12.5 t ha⁻¹ helped in maintaining the soil fertility status after harvest of the crop alone or in combination with fertilizer-P.

Key words: Ashwagandha, phosphorus, farmyard manure, alkaloids, nutrients uptake, soil fertility.

INTRODUCTION

Ashwagandha (*Withania somnifera* L. Dunal), commonly called 'Winter cherry', is a dryland medicinal crop having tremendous marketing potential owing to demand of its roots to the tune of 7000 tonnes and estimated production of 1500 tonnes (Umadevi et al., 2012). Ashwagandha root drug find an important place in Ayurveda (Khanna et al., 2006; Kulkarni and Dhir, 2008) for the treatment of

rheumatic pain, inflammation of joints, nervous disorders, impotence and immature ageing and is considered as 'Indian ginseng' (Khanna et al., 2006; Kulkarni and Dhir, 2008). It belongs to the family 'Solanaceae' and is native to Indian subcontinent. The plant grows erect to a height of 35-75 cm having small green-coloured flowers and orange-red ripe fruit. The past studies have concentrated

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Table 1. Effect of FYM and inorganic phosphorus on growth parameters and yield of alkaloids.

| FYM levels (t/ha) | Plant height (cm) | | | | Overall Mean | No. of primary branches | | | | Overall Mean | Plant spread (cm ²) | | | | Overall Mean | Dry weight (g) of roots (dry weight of shoots in g given in bracket) | | | | Overall Mean | Yield of alkaloids (mg pot ⁻¹) | | | | Overall Mean |
|-------------------|---------------------------------|-------|------|-------|--------------|---------------------------------|-------|-----|-------|--------------|---------------------------------|-------|-------|-------|--------------|--|----------------|----------------|----------------|----------------|--|-------|------|-------|--------------|
| | P levels (kg ha ⁻¹) | | | | | P levels (kg ha ⁻¹) | | | | | P levels (kg ha ⁻¹) | | | | | P levels (kg ha ⁻¹) | | | | | | | | | |
| | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | |
| F0 | 27.6 | 31.4 | 33.2 | 34.6 | 31.7 | 1.4 | 1.9 | 2.3 | 2.5 | 2.0 | 124.7 | 191.1 | 232.3 | 248.8 | 199.2 | 2.97 (4.28) | 3.58 (4.97) | 3.74 (5.43) | 3.86 (5.47) | 3.43 (5.04) | 9.8 | 13.6 | 15.3 | 16.6 | 13.8 |
| F12.5 | 29.4 | 31.6 | 35.5 | 36.1 | 33.1 | 1.6 | 2.1 | 2.4 | 2.6 | 2.2 | 145.3 | 221.7 | 243.3 | 260.1 | 217.6 | 3.50 (5.04) | 3.92 (5.36) | 3.96 (5.58) | 4.03 (5.66) | 3.79 (5.38) | 12.9 | 16.1 | 17.8 | 18.9 | 16.4 |
| F37.5 | 29.7 | 33.8 | 36.2 | 36.8 | 34.1 | 1.7 | 2.2 | 2.5 | 2.6 | 2.3 | 162.9 | 243.3 | 248.8 | 265.9 | 230.2 | 3.69 (5.23) | 4.02 (5.52) | 4.05 (5.77) | 4.08 (5.79) | 3.92 (5.55) | 14.0 | 16.9 | 19.0 | 20.4 | 17.6 |
| Overall mean | 28.9 | 32.3 | 35.0 | 35.8 | | 1.6 | 2.1 | 2.4 | 2.6 | | 144.3 | 218.7 | 241.5 | 258.3 | | 3.39 (4.85) | 3.84 (5.28) | 3.92 (5.59) | 3.99 (5.64) | | 12.2 | 16.9 | 17.4 | 18.6 | |

CD, $p=0.05$; Plant height (cm): Phosphorus = 6.9, FYM = 3.4, phosphorus X FYM = 6.1; No. of primary branches: phosphorus = 3.6, FYM = 1.3, phosphorus X FYM = N.S.; plant spread (cm²): phosphorus = 12.3, FYM = 9.6, phosphorus X FYM = 17.2; dry weight (g) of roots (dry weight of shoots in g given in bracket): phosphorus = 0.08(0.43), FYM = 0.14(0.31), phosphorus X FYM = 0.16(N.S.); yield of alkaloids (mg pot⁻¹): phosphorus = 1.8, FYM = 1.4, phosphorus X FYM = 3.5.

on root growth and biochemical composition in different accessions. There is limited literature available on nutritional studies of ashwagandha with respect to its vegetative and quality parameters. The yield and quality of any crop heavily relies on the knowledge of nutritional requirement and its supply accordingly. Keeping this in view, the present study was an attempt to study the effect of inorganic source of nutrients alone and in combination with farm yard manure (FYM) on plant growth parameters, alkaloids yield, nutrients uptake and post-harvest soil nutrient status under ashwagandha.

MATERIALS AND METHODS

A pot experiment was conducted to study the response of graded levels of P in combination with FYM on plant growth parameters and medicinal quality of ashwagandha (*Withania somnifera* L. Dunal, cv. JA 20) at screen-house, Department of Soil Science, CCS Haryana Agricultural University, Hisar (29°05' N, 75°38' E, 222m elevation). The soil (Typic Torripsamment) used was loamy sand in texture, pH 8.0, EC (1:2) 0.34 dS m⁻¹, Organic Carbon 0.26 %, Available N, P, K were 112.6, 12.0 and 192.0 kg ha⁻¹ respectively. Available (DTPA extractable) Zn, Cu, Fe and

Mn were 0.34, 0.26, 4.05 and 6.87 mg kg⁻¹ respectively. The O.C (%), total NPK in FYM were 38.4, 0.87, 0.29 and 0.73%, respectively. The treatment combination comprised of four levels of phosphorus (0, 12.5, 25 and 37.5 mg P₂O₅ kg⁻¹ soil) applied through KH₂PO₄ and three levels of FYM (0, 12.5 and 25 t ha⁻¹). Experimental data was statistically analyzed by two factor completely randomized design using ANOVA with three replications by using OPSTAT. Basal doses of nitrogen, potassium and zinc were applied through urea, KCl and ZnSO₄ solutions. Nitrogen was applied in two splits, that is, half at the time of sowing and another half at 21 days after sowing. 5 kg soil was placed in each earthen pot after giving respective treatments on a polythene sheet. The crop was harvested after 120 days of sowing and observations were recorded separately in each pot. All the samples were analyzed by following standard laboratory procedures. Total alkaloids (%) in ashwagandha were determined by extraction with chloroform as described by Rajpal (2002).

RESULTS AND DISCUSSION

Effect on growth parameters

It can be seen from Table 1 that application of fertilizer-P at the rate of 12.5, 25 and 37.5 mg kg⁻¹ soil resulted in increase in plant height by 11.8, 21.1 and 23.9% over control. Though P at all levels

increased the plant height but the increase was significant up to application level of 12.5 mg P₂O₅ kg⁻¹ soil (32.3cm) over control (28.9 cm). Application of FYM also helped in increasing the height of ashwagandha at all levels but the significant increase of 4.4% was observed at level of 12.5 t ha⁻¹ over control. Wafaa et al. (2006) also reported almost similar results. Phosphorus fertilizer along with FYM resulted in increased plant height at all levels of FYM up to 12.5 mg P₂O₅ kg⁻¹ soil. Aishwath (2004) also reported increase in plant height by application of phosphorus fertilizer.

Data also indicated that number of primary branches increased significantly with 12.5 mg P₂O₅ kg⁻¹ soil (2.1) to the extent of 31.3% over control (1.6). However the increase between that of 25 mg P₂O₅ kg⁻¹ soil (2.4) and 37.5 mg P₂O₅ kg⁻¹ soil (2.6) was found to be non-significant. Kothari et al. (2005) also reported increase in number of branches by application of P-fertilizer. FYM at the rate of 12.5 t ha⁻¹ (2.2) also increased the average number of primary branches over control (2.0) but this increase (10.0% over control) was on a par with that of FYM at the rate of 25 t ha⁻¹ (2.3, that is, 15.0% over control). Somnath et al. (2005)

ported significant increase in yield attributing characters by application of FYM.

A perusal of the data (Table 1) indicated that increasing level of P increased the plant spread by 51.6, 67.4 and 79.0% over control by application of 12.5, 25 and 37.5 mg P₂O₅ kg⁻¹ soil. Almost similar results were reported by Kothari et al. (2005) and Somnath et al. (2005). FYM helped in increase of plant spread at all levels, that is, 12.5 and 25 t ha⁻¹ (217.6 and 230.2 cm² respectively) over control (199.2 cm²). Almost similar results were reported by Somnath et al. (2005). Inorganic phosphorus applied along with FYM also indicated the positive effect on plant spread and the interaction effect was significant up to 12.5 mg P₂O₅ kg⁻¹ soil at all levels of FYM application. Our results are in agreement with that of Joy et al. (2005) and Wafaa et al. (2006).

Data also indicated that application of fertilizer-P at the rate of 12.5, 25 and 37.5 mg P₂O₅ kg⁻¹ soil which resulted in mean dry weight of ashwagandha roots to the extent of 13.3, 15.6 and 17.7% increase over control. It could be observed that there was progressive increase in the dry weight of ashwagandha roots by increasing the rate of phosphorus application; however, the increase was significant up to application level of 25 mg P₂O₅ kg⁻¹ soil. Kothari et al. (2005) and Somnath et al. (2005) also reported increased dry weight by application of phosphorus fertilizer. FYM at the rate of 25 t ha⁻¹ (3.92 g pot⁻¹) significantly increased the average fresh weight of roots over control (3.43 g pot⁻¹) and the extent of increase was 14.3%. Along with phosphorus, 12.5 t FYM ha⁻¹ was found to be the appropriate dose for increase in dry weight of roots significantly over control. Chauhan et al. (2005) and Joy et al. (2005) also reported increase in dry matter by application of FYM.

A critical study of the data (Table 1) revealed that phosphorus application up to 12.5 P₂O₅ kg⁻¹ soil enhanced the dry weight of ashwagandha shoot to 5.28 g and the corresponding increase was 8.9% over control. This increase was on a par with increase by application levels of 25 and 37.5 kg⁻¹ P₂O₅ soil. Pratibha and Korwar (2005) also reported increase in biomass by application of phosphorus fertilizer. FYM at all levels increased the dry weight of shoot but the significant increase was observed up to application of FYM at the rate of 12.5 t ha⁻¹ over control (6.7%). Positive effect on plant growth parameters had been demonstrated by Qian and Schoenau (2010), Tantawy et al. (2010) and Wenyi et al. (2011) after application of inorganic phosphorus and by Raafat et al. (2011), Raja et al. (2011) and Singh et al. (2011) after application of FYM. However, the extent of effect varies depending upon soil, fertilizer level and crop.

Effect on yield of alkaloids

Data (Table 1) also indicated that application of phosphorus at the rate of 12.5 mg P₂O₅ kg⁻¹ soil significantly increased the alkaloids yield (mg pot⁻¹) of ashwagandha

roots up to 38.5% over control. Balakumbahan et al. (2005) and Kolodziej et al. (2009) also reported almost similar results of increase in alkaloids by application of phosphorus fertilizer. FYM at the rate of 12.5 t ha⁻¹ increased the alkaloids yield up to 18.8% over control. Kumar (2011) and Lakshmi et al. (2011) showed improvement in quality of crops by application of FYM.

Effect on nutrients uptake by shoot and roots of ashwagandha

N uptake by shoot increased significantly by application of fertilizer-P (Table 2) and the maximum average increase was 23.8% by application of 37.5 mg P₂O₅ kg⁻¹ soil (103.0 mg pot⁻¹) over control. Application of FYM at the rate of 12.5 and 25 t ha⁻¹ increased the N uptake by 8.8 and 14.1% respectively, over control and the increase was on a par between 12.5 (96.5 mg pot⁻¹) and 25 t ha⁻¹ (101.2 mg pot⁻¹). Patil et al. (2005) also reported that supplementing nitrogen promoted the uptake of nitrogen. The application of P and P + FYM showed an increase in N-uptake by ashwagandha roots over control (Table 3). The increase in N-uptake was primarily due to the increase in dry weight of roots by these parameters. Highest values of N uptake by ashwagandha roots (93.9 mg pot⁻¹) was obtained with 37.5 mg P₂O₅ kg⁻¹ soil + 25 t FYM ha⁻¹ which was on a par with that of 88.6 mg pot⁻¹ (25 mg P₂O₅ kg⁻¹ soil + 12.5 t FYM ha⁻¹). In the absence of FYM, mineral-P increased N-uptake by ashwagandha roots up to 16.1% at application level of 37.5 mg P₂O₅ kg⁻¹ soil. Uptake of phosphorus by ashwagandha shoots was positively and significantly enhanced by increasing level of mineral-P and mineral-P + FYM application. Addition of mineral-P at the rate of 12.5, 25 and 37.5 mg P₂O₅ kg⁻¹ soil increased average P-uptake by 25.7, 49.7 and 59.1%, respectively, over control. Almost similar results were reported by Kadlag et al. (2005) and Patil et al. (2005). Also, addition of FYM at the rate of 12.5 and 25 t ha⁻¹ enhanced the P-uptake by 16.3 and 25.2%, respectively, over control. P-uptake by ashwagandha roots showed an increasing trend with increasing dose of fertilizer-P alone. The average extent of increase was 12.3 mg pot⁻¹ higher than the control with application of 37.5 mg P₂O₅ kg⁻¹ soil. However, with application of 25 t FYM ha⁻¹, average increase in P-uptake was 29.3% over control. The positive effect of FYM on P concentration may be attributed primarily to the enhanced availability of native P, increase in P solubility and reduction in phosphate fixing capacity (Singh et al., 1983). Secondly, organic acids and humic substances produced during decomposition of organic manures could have increased the availability of P by chelating Ca, Fe and Al (Singh et al., 1981), and forming water-soluble organic metallic phosphate (Sinha, 1975). Application of mineral-P at the rate of 37.5 mg P₂O₅ kg⁻¹ soil increased average K-uptake by ashwagandha shoot up to 50.0% over control. This might be due to synergistic relationship between N and K. Misas et al. (2003) also

Table 2. Effect of FYM and inorganic phosphorus on nutrients uptake by shoot of ashwagandha.

| FYM level (t/ha) | N uptake by shoot (mg pot ⁻¹) | | | | Overall mean | P uptake by shoot (mg pot ⁻¹) | | | | Overall mean | K uptake by shoot (mg pot ⁻¹) | | | | Overall mean |
|------------------|---|-------|-------|-------|--------------|---|-------|------|-------|--------------|---|-------|-------|-------|--------------|
| | P levels (kg ha ⁻¹) | | | | | P levels (kg ha ⁻¹) | | | | | P levels (kg ha ⁻¹) | | | | |
| | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | |
| F0 | 71.0 | 86.5 | 97.2 | 100.0 | 88.7 | 13.3 | 18.4 | 23.3 | 25.7 | 20.2 | 54.4 | 73.6 | 88.5 | 96.8 | 78.3 |
| F12.5 | 87.2 | 94.3 | 100.4 | 104.1 | 96.5 | 17.6 | 22.5 | 25.7 | 28.3 | 23.5 | 71.6 | 86.8 | 97.6 | 105.3 | 90.3 |
| F37.5 | 91.5 | 99.4 | 106.2 | 107.7 | 101.2 | 20.4 | 23.7 | 27.7 | 29.5 | 25.3 | 81.6 | 93.8 | 104.4 | 109.4 | 97.3 |
| Overall mean | 83.2 | 93.4 | 101.3 | 103.9 | | 17.1 | 21.5 | 25.6 | | | 69.2 | 84.7 | 96.8 | 103.8 | |

CD, (p=0.05); N uptake by shoot: Phosphorus = 7.6, FYM = 5.4, phosphorus X FYM = 13.8; P uptake by shoot: phosphorus = 3.8, FYM = 3.2, phosphorus X FYM = 4.9; K uptake by shoot: phosphorus = 10.8, FYM = 9.3, phosphorus X FYM = 17.7.

Table 3. Effect of FYM and inorganic phosphorus on nutrients uptake by roots of ashwagandha.

| FYM levels (t/ha) | N uptake by roots (mg pot ⁻¹) | | | | Overall mean | P uptake by roots (mg pot ⁻¹) | | | | Overall mean | K uptake by roots (mg pot ⁻¹) | | | | Overall mean |
|-------------------|---|-------|------|-------|--------------|---|-------|------|-------|--------------|---|-------|------|-------|--------------|
| | P levels (kg ha ⁻¹) | | | | | P levels (kg ha ⁻¹) | | | | | P levels (kg ha ⁻¹) | | | | |
| | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | | P0 | P12.5 | P25 | P37.5 | |
| F0 | 58.5 | 78.4 | 84.9 | 90.3 | 78.0 | 10.7 | 17.5 | 21.3 | 24.3 | 18.4 | 40.4 | 56.2 | 65.1 | 70.6 | 58.1 |
| F12.5 | 72.1 | 88.6 | 91.5 | 95.1 | 86.8 | 14.7 | 21.6 | 24.2 | 27.0 | 21.9 | 51.8 | 64.3 | 70.9 | 75.4 | 65.6 |
| F37.5 | 80.1 | 91.7 | 94.4 | 96.3 | 90.6 | 17.3 | 23.3 | 26.7 | 28.1 | 23.8 | 58.7 | 68.7 | 74.1 | 77.1 | 69.6 |
| Overall mean | 70.2 | 86.2 | 90.3 | 93.9 | | 14.2 | 20.8 | 24.1 | 26.5 | | 50.3 | 63.1 | 70.0 | 74.4 | |

CD, (p=0.05); N uptake by roots: Phosphorus = 3.9, FYM = 6.2, phosphorus X FYM = 12.7; P uptake by roots: Phosphorus = 3.3, FYM = 2.6, phosphorus X FYM = 5.7; K uptake by roots: phosphorus = 6.7, FYM = 6.2, phosphorus X FYM = 13.7.

reported that P fertilizer application increased the K concentration in plants. Addition of phosphorus (either alone or in combination with FYM) had a marked effect on K-uptake by roots of ashwagandha. Application of fertilizer-P at the rate of 12.5, 25 and 37.5 mg P₂O₅ kg⁻¹ soil increased the average K uptake by roots to the extent of 25.4, 39.2 and 47.9% over control. The extent of increase by application of FYM at the rate of 12.5 and 25 t ha⁻¹ was 12.9 and 19.8%

over control. Sepat et al. (2010), Sepehya et al. (2012) and Singh et al. (2011) also showed the increase in NPK content by increased dose of FYM.

Effect on soil nutrient status after harvest of ashwagandha

From perusal of data in Table 4, it might be observed that the average organic carbon content of soil increased up to 7.4% with the application of

highest level of P. The improvement in organic carbon content due to P supply may be attributed to better plant growth and hence large amount of root residues remain in soil as undecomposed which may increase the carbon content of soil. Higher organic carbon was observed in FYM treated soil alone or in combination with P-fertilizer. Average available N content of soil decreased by 5.4, 8.1 and 9.8% over control with application of 12.5, 25 and 37.5 mg P₂O₅ kg⁻¹ soil, respectively.

Table 4. Effect of FYM and inorganic phosphorus on soil macronutrient status.

| FYM levels (t/ha) | Organic carbon (%) | | | | | Overall mean | Available-N (kg ha ⁻¹) | | | | Overall mean | Available-P (kg ha ⁻¹) | | | | Overall mean | Available-K (kg ha ⁻¹) | | | | Overall mean |
|-------------------|---------------------------------|-------|------|-------|---------------------------------|--------------|------------------------------------|-------|---------------------------------|-------|--------------|------------------------------------|---------------------------------|-------|------|--------------|------------------------------------|-------|-------|-------|--------------|
| | P levels (kg ha ⁻¹) | | | | P levels (kg ha ⁻¹) | | | | P levels (kg ha ⁻¹) | | | | P levels (kg ha ⁻¹) | | | | | | | | |
| | P0 | P12.5 | P25 | P37.5 | P0 | | P12.5 | P25 | P37.5 | P0 | | P12.5 | P25 | P37.5 | P0 | | P12.5 | P25 | P37.5 | | |
| F0 | 0.24 | 0.26 | 0.27 | 0.27 | 0.26 | 111.8 | 104.6 | 102.5 | 101.7 | 105.1 | 11.8 | 13.9 | 14.4 | 14.6 | 13.7 | 190.2 | 187.6 | 185.4 | 183.3 | 186.6 | |
| F12.5 | 0.27 | 0.28 | 0.29 | 0.30 | 0.29 | 117.2 | 112.3 | 108.9 | 105.4 | 110.9 | 16.8 | 18.9 | 19.4 | 19.7 | 18.7 | 224.6 | 217.3 | 208.6 | 204.7 | 213.8 | |
| F37.5 | 0.29 | 0.30 | 0.31 | 0.31 | 0.30 | 121.4 | 114.7 | 110.6 | 109.2 | 114.0 | 19.6 | 21.1 | 22.8 | 23.1 | 21.6 | 245.4 | 238.9 | 232.5 | 229.4 | 236.6 | |
| Overall mean | 0.27 | 0.28 | 0.29 | 0.29 | | 116.8 | 110.5 | 107.3 | 105.4 | | 16.1 | 18.0 | 18.9 | 19.1 | | 220.1 | 214.6 | 208.8 | 205.8 | | |

CD, ($p=0.05$); Organic carbon: Phosphorus = 0.02, FYM = 0.02, phosphorus X FYM = N.S; available-N: phosphorus = 3.0, FYM = 5.2, phosphorus X FYM = N.S; available-P: Phosphorus = 0.9, FYM = 3.8, Phosphorus X FYM = N.S; available-K: phosphorus = 5.2, FYM = 12.3, phosphorus X FYM = 15.7.

Table 5. Effect of FYM and inorganic phosphorus on soil DTPA extractable micronutrients status.

| FYM level (t/ha) | DTPA extractable zinc (mg kg ⁻¹) | | | | | Overall mean | DTPA extractable Cu (mg kg ⁻¹) | | | | Overall mean | DTPA extractable Fe (mg kg ⁻¹) | | | | Overall mean | DTPA extractable Mn (mg kg ⁻¹) | | | | Overall mean |
|------------------|--|-------|------|-------|---------------------------------|--------------|--|------|---------------------------------|------|--------------|--|---------------------------------|-------|------|--------------|--|------|-------|------|--------------|
| | P levels (kg ha ⁻¹) | | | | P levels (kg ha ⁻¹) | | | | P levels (kg ha ⁻¹) | | | | P levels (kg ha ⁻¹) | | | | | | | | |
| | P0 | P12.5 | P25 | P37.5 | P0 | | P12.5 | P25 | P37.5 | P0 | | P12.5 | P25 | P37.5 | P0 | | P12.5 | P25 | P37.5 | | |
| F0 | 0.41 | 0.39 | 0.39 | 0.38 | 0.39 | 0.28 | 0.24 | 0.22 | 0.23 | 0.24 | 4.07 | 3.99 | 3.97 | 3.95 | 3.99 | 3.88 | 3.84 | 3.83 | 3.83 | 3.85 | |
| F12.5 | 0.46 | 0.42 | 0.40 | 0.41 | 0.42 | 0.31 | 0.27 | 0.26 | 0.24 | 0.27 | 4.18 | 4.06 | 4.01 | 4.03 | 4.07 | 3.95 | 3.91 | 3.87 | 3.85 | 3.89 | |
| F37.5 | 0.48 | 0.45 | 0.42 | 0.42 | 0.44 | 0.33 | 0.27 | 0.25 | 0.23 | 0.27 | 4.24 | 4.13 | 4.09 | 4.05 | 4.13 | 3.98 | 3.94 | 3.91 | 3.90 | 3.93 | |
| Overall mean | 0.45 | 0.42 | 0.40 | 0.40 | | 0.31 | 0.26 | 0.24 | 0.23 | | 4.16 | 4.06 | 4.02 | 4.01 | | 3.94 | 3.90 | 3.87 | 3.86 | | |

CD, ($p=0.05$); DTPA extractable zinc: Phosphorus = 0.02, FYM = 0.03, Phosphorus X FYM = N.S; DTPA extractable Cu: Phosphorus = 0.04, FYM = 0.02, Phosphorus X FYM = N.S; DTPA extractable Fe: phosphorus = 0.04, FYM = 0.07, phosphorus X FYM = 0.08; DTPA extractable Mn: phosphorus = 0.03, FYM = N.S, phosphorus X FYM = N.S.

This decrease might be attributed to better crop growth with high rates of phosphorus addition resulting in higher uptake of nitrogen. FYM single-handedly augmented the average available nitrogen content of the soil from 105.1 (control) to 114.0 mg kg⁻¹ soil (25 t FYM ha⁻¹). Also, there was 36.5% (12.5 t FYM ha⁻¹) to 57.7% (25 t FYM ha⁻¹) increase in average available phosphorus status of soil over control by application of different FYM treatments in ashwagandha. The increase in available phosphorus content with increased P levels may be attributed to the residual effect of applied P and increase in mineralization of organic matter.

There was significant decrease in available K content of soil with addition of successive levels of fertilizer-P but significant increase with the application of FYM. This has been demonstrated by Sepatetal.(2010)andThakur et al.(2011).Natarajan et al. (2005) also reported decrease in K-status of the soil by application of chemical fertilizers and added that organic manure application enhanced the available K-status of the soil by application of chemical fertilizers. The decrease with successive addition of fertilizer-P may have been due to better crop growth with high rates of P addition resulting in higher uptake of K. The increase in available K

with addition of FYM might be due to the organic acids, which were released during microbial decomposition of FYM; these helped in solubility of native potash as a result of which increase in available K content occurred.

11.1% decrease in DTPA extractable Zn was recorded by application of 25 mg P₂O₅ kg⁻¹ soil over control (Table 5). FYM at the rate of 25 t ha⁻¹ recorded increase in DTPA extractable Zn over control to the extent of 12.8% over control. Application of 12.5 mg P₂O₅ kg⁻¹ soil recorded significant reduction in DTPA extractable Cu content of post harvest soil over control (16.1%). FYM at the

rate of 12.5 t ha⁻¹ proved to be effective in maintaining the soil fertility in terms of DTPA extractable Cu content of the post harvest soil to the extent of 12.5% over control. Increasing dose of P-fertilizer decreased the DTPA extractable Fe status in soil after harvest of ashwagandha and the decrease was significant up to 12.5 mg P₂O₅ kg⁻¹ soil. Data further indicated that the application of 12.5 mg P₂O₅ kg⁻¹ soil decreased the DTPA extractable Mn status of the soil to the extent of 1.0% over control and above this dose; the effect was on a par with this level. FYM at all levels was found to be non-significant in terms of DTPA extractable Mn content of the post harvest soil. Datta et al. (2010), Reddy (2010) and Singh et al. (2012) reported that addition/substitution of FYM recorded significantly higher level of micronutrients uptake over other treatments.

This study shows that the growth of ashwagandha and yield of alkaloids is enhanced significantly by application of P and FYM while maintaining the nutrient status of the soil. Therefore, the two components should invariably form an input part for better economic yield of the drug. The low satisfactory and high values for the yield of the drug reported in the article could be used to elaborate a fertilizer recommendation system for ashwagandha.

REFERENCES

- Aishwath OP (2004). Mineral nutrition and growth of *Withania somnifera*. J. Trop. Med. Plants 5(1): 111-118.
- Balakumbahan R, Sadasakthi A, Kumar S, Saravanan A (2005). Effects of inorganic and biofertilizers on biomass and alkaloids yield of keelaneli (*Phyllanthus amarus*). J. Med. Aromat. Plant Sci. 27(3):26-28.
- Chauhan HS, Aparbal S, Singh HP, Singh AK, Chattopadhyay A, Raj Kumari, Prasad A (2005). Influence of FYM and NPK fertilizers on growth and yield of safed musli (*Chlorophytum borivilianum*) production. J. Med. Aromat. Plant Sci. 22(1B): 447-449.
- Datta SP, Rattan RK, Suresh C (2010). Labile soil organic carbon, soil fertility and crop productivity as influenced by manure and mineral fertilizers in the Tropics. J. Plant Nutr. Soil Sci. 173(5): 715-726.
- Joy PP, Savithri KE, Mathew S, Thomas J, Kurien K (2005). Effect of sole and combined application of FYM and fertilizer on growth, yield and quality of black musli (*Curculigo orchoides* Gaerth). J. Med. Aromat. Plant Sci. 27(3): 684-692.
- Kadlag AD, Kolekar RG, Kasture MC, Sawale DD (2005). Effect of integrated plant nutrient supply on yield, quality and nutrient uptake of okra. Ann. Plant Physiol. 19(2): 191-195.
- Khanna PK, Kumar A, Ahuja A, Kishen Kaul M (2006). Biochemical composition of roots of *Withania somnifera* (L.) Dunal. Asian J. Plant Sci. 5: 1061-1063.
- Kolodziej B, Wisniewski J, Bielinska EJ (2009). Protective effect of foliar fertilization on American ginseng. Acta Hort. 826: 351-356.
- Kothari SK, Singh CP, Kumar YV (2005). Growth and yield of *Spilanthes acmella* (syn. *S. mauritiana*) roots and its cultivation economics as influenced by nitrogen and phosphorus application under semi-arid tropics. J. Med. Aromat. Plant Sci. 27(2): 283-286.
- Kulkarni SK, Dhir A (2008). *Withania somnifera*: An Indian ginseng. Progress Neuro-Psychopharmacol. Biol. Psychiatry 32(5): 1093-1105.
- Kumar M (2011). Yield and quality of potato (*Solanum tuberosum*) tubers as influenced by nutrient sources under rainfed condition of Meghalaya. Indian J. Agron. 56(3): 260-266.
- Lakshmi CSR, Sreelatha T, Usha Rani T, Rao SRK, Naidu NV (2011). Effect of organic manures on soil fertility and productivity of sugarcane in north coastal zone of Andhra Pradesh. Indian J. Agric. Res. 45(4): 307-313.
- Misas Y, Kostadinova S, Tomov T (2003). Uptake of nitrogen, phosphorus and potassium by wheat cv. Prelom. Pochvoznanie Agrokhimiya-i-Ekologiya 38(1): 24-27.
- Natarajan S, Kuppuswamy G, Arivazhagan K, Thirukumar K (2005). Effect of organic manure application in rice. Oryza 42(4): 319-320.
- Patil PV, Chawade, PB, Solanke, AS, Kulkarni VK (2005). Effect of flyash and FYM on nutrient uptake and yield of onion. J. Soils Crops 15(1): 187-192.
- Pratibha G, Korwar GR (2005). Influence of stages of harvest, nitrogen and phosphorus fertilization on biomass yield and dye in indigo. J. Med. Aromat. Plant Sci. 27(1): 10-15.
- Qian P, Schoenau J (2010). Effects of conventional and controlled release phosphorus fertilizer on crop emergence and growth response under controlled environment conditions. J. Plant Nutr. 33(9): 1253-1263.
- Raafat N, Zaki, Tharwat E, Radwan E (2011). Improving wheat grain yield and its quality under salinity conditions at a newly reclaimed soil by using different organic sources as soil or foliar applications. J. Appl. Sci. Res. 7(1): 442-455.
- Raja W, Bhat AS, Medhi D (2011). Production potential of fodder oat (*Avena sativa* L.) based cropping sequences with different sources of nitrogen under Temperate climatic conditions of Kashmir. Appl. Biol. Res. 13(2): 89-93.
- Rajpal V (2002). Standardization of botanicals: Testing and extraction methods of medicinal herbs. V1. New Delhi: Eastern Publications.
- Reddy TP, Umadevi M, Chandrasekhar Rao P (2010). Effect of fly ash and farm yard manure on soil properties and yield of rice grown on an Inceptisol. Agric. Sci. Dig. 30(4): 281-285.
- Sepat RN, Rai RK, Dhar S (2010). Planting systems and integrated nutrient management for enhanced wheat (*Triticum aestivum*) productivity. Indian J. Agron. 55(2): 114-118.
- Sepehya S, Bhardwaj SK, Dixit SP, Dhiman S (2012). Effect of integrated nutrient management on yield attributes, yield and NPK uptake in garden pea (*Pisum sativum* L.) in acid alfisol. J. Food Legumes 25(3): 247-249.
- Singh B, Rana DS, Kapur ML, Sharma KN, Bhandari, AL (1983). Evaluation of farm yard manure applied along with fertilizers to maize (*Zea mays*) and wheat (*Triticum aestivum*). Indian J. Agron. 28:285-289.
- Singh BP, Chahal RS, Singh M (1981). Fertilizer management through organic and inorganic fertilizers in bajra-wheat crop sequence. Fert. News. 26: 16-19.
- Singh RJ, Singh J, Ahlawat IPS (2012). Lint yield, fibre quality and its nutrient uptake in Bt cotton (*Gossypium hirsutum*)-groundnut (*Arachis hypogaea*) intercropping system using different fertility levels. Indian J. Agric. Sci. 82(12): 1039-1043.
- Singh RN, Singh S, Prasad SS, Singh VK, Kumar P (2011). Effect of integrated nutrient management on soil fertility, nutrient uptake and yield of rice-pea cropping system on an upland acid soil of Jharkhand. J. Indian Soc. Soil Sci. 59(2): 158-163.
- Sinha MK (1975). Effect of straw application on yield and phosphorus nutrition of crops. Plant Soil. 43: 537-545.
- Somnath, Bhaskar S, Sreenivasamurthy CA (2005). Influence of FYM, inorganic fertilizers (NPK) and sources of potassium on the yield of *Coleus forskohlii*. J. Med. Aromat. Plant Sci. 27(1): 16-19.
- Tantawy AS, Abdel-Mawgoud AMR, El-Nemr MA, Abou-Hussein SD (2010). Responses of squash plants to different foliar concentrations of phosphorus-potassium compound fertilizer. J. Appl. Sci. Res. 6(12): 1996-1999.
- Thakur R, Sawarkar SD, Vaishya UK, Singh M (2011). Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soyabean-wheat intensive cropping of a vertisol. J. Indian Soc. Soil Sci. 59(1): 74-81.
- Umadevi M, Rajeswari R, Sharmila Rahale C, Selvavenkadesh S, Pushpa R, Sampath Kumar KP, Bhowmik D (2012). Traditional and medicinal uses of *Withania somnifera*. Pharma Innov. 1(9): 102-110.
- Wafaa MTE, Gehan HV, Laila KMA (2006). Plant growth and nutrients uptake as influenced by application of farmyard manure and some natural minerals to sandy soils. Arab Univ. J. Agric. Sci. 14(1): 213-234.
- Wenji D, Jing Q, Jiyue Li, Yan Z, Lishui N, Zhiyi Z (2011). Interactions between soil water content and fertilizer on growth characteristics and biomass yield of Chinese white poplar (*Populus tomentosa* Carr.) seedlings. Soil Sci. Plant Nutr. 57(2): 303-312.