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GROWTH ANALYSIS AND PHENOLOGICAL PARAMETERS OF ASHWAGANDHA (*WITHANIA SOMNIFERA* L.) IN INTERCROPPED WITH PULSES AND OILSEEDS

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Abstract

A field experiment was conducted during *kharif* 2009 and 2011 at Research Farm, JNKVV, Jabalpur (M.P.), India to find out the suitable ashwagandha based intercropping system for higher productivity. The experiment emprises as 05 intercropping system (Ashwagandha + red gram, Ashwagandha + green gram, Ashwagandha + soybean, Ashwagandha + sesame and Ashwagandha + niger) with 02 row ratio (3:1 and 4:1) along with 01 sole ashwagandha and, all 11treatment were tested in randomized block design with 04 replication. At 120 DAS stage, the maximum LAI was obtained 5.18 in ashwagandha sole which was decline with advancement stages. However, between 150 DAS – maturity stage, the maximum CGR 7.33 mg/m^2/day were obtained Ashwagandha + soybean following Ashwagandha + red gram (4:1) and Ashwagandha + niger (4:1). Maximum RGR were observed at 0-30 days stage which NAR was statistically higher at 0-30 days and 90-120 days under sole and intercrop Ashwagandha. It was declined with advancement of stage of crop. Relative growth rate was noted significantly higher in Ashwagandha + soybean (3:1 & 4:1) 149.63 mg/g/day followed by Ashwagandha + red gram and sole ashwagandha (149.23 mg/g/day) . However, NAR noted significantly greater in Ashwagandha + soybean (3:1) followed by Ashwagandha + niger (3:1) and red gram (4:1). Ashwagandha grown with pulses or oilseeds as intercrops resulted in 3 to 4 days earlier start of reproduction phase as compared to that when ashwagandha was grown as a sole crop. Accordingly days to 50 per cent flowering, first fruit appearance and physiological maturity attained earlier under all the intercropping treatments over sole crop of ashwagandha. Other cropping systems was recorded almost equal phenological parameters at different growth the stages. The sole crop Ashwagandha significantly produced higher tuber yields (518 kg/ha.) over all other intercropped stands producing tuber yields between 392 to 430 kg/ha. The tuber yield of ashwagandha was found remarkable higher under 4:1 row proportion of ashwagandha + intercrop than 3:1 row ratio. However, Ashwagandha + sesame and niger was obtained numerically higher yield of ashwagandha than other intercropping system.

Key words : Ashwagandha, red gram, green gram, soybean, sesame, niger, intercropping system.

Introduction

Intercropping is a simple but inexpensive strategy and has been recognized as a potential benefit technology for increased crop production (Olsen *et al*., 1984). The most common advantage of the intercropping is the production of the greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crop of different rooting ability, canopy, stracture, height and nutrient requirement based on the complementary utilization of the growth resources by the component crop. Better soil use of nutrients can be possible due to difference in rooting pattern which may also occur due to mutual avoidance of different rooting system (Trenbath, 1974). The success of any intercropping system depends mainly on selection of component crops. The component crops should invariably have different growth rhythms and rooting patterns.

Ashwagandha (*Withania somnifera* L.) is known as Indian ginseng, is an important ancient plant belongs to Solanaceae family, the roots of which have been employed

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in Indian traditional systems of medicine, *Ayurveda* and *Unani,* It is an erect branching under shrub reaching about 0.50-1.00 m in height. The eastimated production of ashwagandha roots in India is more than 1500 tonnes and the annual requirement is about 9000 tonnes necessitating the increase in its cultivation and higher production (Chamchaiow, 1980). The demand of pulses and oilseeds is increasing due to increased human population. It is therefore essential to increase their production under different cropping systems. The information on productivity and economical gain from Ashwagandha intercropped with pulses and oilseeds is lacking for *Kymore Plateau* of Madhya Pradesh. Hence, the present study was conducted to find the suitable ashwagandha based intercropping system for enhancing growth and productivity of Ashwagandha with oilseed and pulses.

Materials and Methods

The field experiment was conducted at Research Farm, College of Agriculture, J.N.K.V.V., Jabalpur (M.P.) during *kharif* of 2009 and 2011. The soil was clay-loam with 7.5 pH. The soil was low in organic carbon (0.48%) and available nitrogen (230.2 kg/ha), medium in available phosphorus (13.80 kg/ha) and high (371.70 kg/ha) available potassium. The rainfall received 1471 and 1712 mm, in 43 and 59 rainy days, the mean maximum and minimum temperature were 31^0C and 30^0C and 19^0C and 18^0C, the relative humidity ranged from 52 to 87% and 55 to 61% during two consecutive experimental period. The treatment comprised 05 intercropping system (Ashwagandha + red gram, Ashwagandha + green gram, Ashwagandha + soybean, Ashwagandha + sesame and Ashwagandha + niger) with 02 row ratio each (3:1 and 4:1) along with one sole Ashwagandha. In all 11 treatments with 04 replications were tested in randomized block design.

The variety and seed rate of Ashwagandha, red gram, green gram, soybean, sesame and niger were JA 134, 05 kg/ha; ICPH 2671, 10 kg/ha; K851, 25 kg/ha; JS 97-52, 50 kg/ha; JTS 8, 02 kg/ha and JNC 1; 02, kg/ha, respectively, with the spacing between sole ashwagandha and intercrops 30 cm apart. The crops were sown on date 26 June, 2009 and 30 June, 2011. The recommended dose of fertilizers was 40 kg N + 20 kg P_2O_5 + 20 kg K_2O /ha for the Ashwagandha, sesame, and niger, while it was as 20 kg N + 60 Kg P_2O_5 + 20 kg K_2O/ha for red gram, green gram and soybean. Total two irrigations were applied in Ashwagandha and red gram in month of October during the both years. The ashwagandha, red gram, green gram, soybean, sesame and niger crops were harvested on 27 Dec, 27 Nov, 29 Aug., 15 Oct, 25, Dec, 20 Oct in 2009 and 28 Dec, 29 Nov, 30 Aug., 17 Oct, 27, Dec, 22 Oct in 2011, respectively. The Ashwagandha was dug out by *khurpi* to protect the damage of roots. All the package and practices were adopted as per recommended to various crops. Ashwagandha equivalent yield (AEYs), LAI, CGR and NAR was calculated as per given formula given by Watson (1952).

Leaf area index

LAI was calculated as per formula given by Watson (1952).

$$LAI = \frac{\text{Leaf area/m}^2}{\text{Ground area/m}^2}$$

The crop growth ratio is relative rate of is increase of production of the dry matter of plant over previously present dry matter per unit time, determined as suggested by Watson (1952).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \text{ (g/m}^2\text{/day)}$$

Where, W_2 and W_1 are dry weight of plants at t_2 and t_1 time intervals. However, mean relative growth rate (RGR) is expressed as increase of plant materials per unit of plant materials present per unit of time. (Blackman, 1968). Where, loge W_1 and loge W_2 are the natural log of dry weight at time t_2 and t_1.

$$RGR = \frac{\text{Loge } W_2 - \text{Loge } W_1}{t_2 - t_1} \text{ (g/g/day)}$$

Net Assimilation rate (NAR) is actual photosynthesis accumulated by the plant through plant leaves per unit area and time. Determined as suggested by Watson (1952)

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\text{Loge } L_2 - \text{Loge } L_1)}{(L_2 - L_1)} \text{ (g/m}^2\text{/day)}$$

Where, L_1 and L_2 are leaf area and dry weight of plants at time t-$_2$ and L_2 are leaf area and dry weight of plant at time t_2.

Results and Discussion

Growth analysis parameter

LAI of Ashwagandha as affected by different cropping systems during entire growth period at monthly intervals in both years of investigation. It is evident from the data given in the said table that LAI values successively increased due to advancement in the growth stages of crop up to 120 DAS and then it showed declining trend upto maturity stage. It is also apparent from the data that rate of increment in LAI values was most rapid during the

period between 60 DAS to 120 DAS and thereafter it slowed down till the maturity. Intercropping of companion crops *viz*. red gram, green gram, soybean, sesame and niger with Ashwagandha in 3:1 as well as 4:1 row proportions did not show any remarkable change in LAI values of Ashwagandha over, it is sole stand at any of the growth stages during both years of investigation. Thus, it is clear that growth of Ashwagandha was unaffected by intercropping.

The CGRs of Ashwagandha recoded at its successive growth stages under different treatments during both years of investigation as well as their mean values of both years. The CGR of Ashwagandha showed a leaner till to maturity, but rate of increment in CGR was slowed down during the period between 90 to 150 DAS.

It is clear from 2-year mean data that CGR values ranged between 2.83 to 2.97 mg/m^2/day at 30 DAS stage under different intercropping systems. The variations in CGR values between different treatments were significant. It was statistically higher in Ashwagandha + soybean (3:1 and 4:1 row ratio) followed by sole Ashwagandha, Ashwagandha + niger (3:1) and Ashwagandha + red gram (4:1). Similarly, at 60 days CGR was observed significantly superior under Ashwagandha + green gram (4:1) and Ashwagandha + niger (4:1) intercropping system. However at 90 days significantly higher CGR was noted in Ashwagandha + sole, Ashwagandha + green gram (3:1), Ashwagandha + red gram/niger (4:1). At later stage of Ashwagandha the pattern of CGR was changed. It was recorded significantly higher in Ashwagandha sole, Ashwagandha + niger (3:1) and Ashwagandha + sesame (4:1) at 120 days; sole Ashwagandha, Ashwagandha + red gram (3:1) and Ashwagandha + niger (3:1) at 150 days and Ashwagandha + soybean (3:1) at maturity. Therefore, it is clear that rate of dry matter accumulation by the Ashwagandha per unit area and time was almost similar in its sole and some intercropped stands. It means the growth of Ashwagandha was qutie unaffected by introducing some of the intercrops as *viz*. red gram, green gram, soybean, sesame and niger either in 3:1 or 4:1 row proportions at different stage of crop growth.

The RGR values of Ashwagandha were maximum (148.10 to 149.63 mg/g/day) under all treatments at very early stage (30 DAS), which declined gradually till the maturity. There was significantly variation between the RGRs due to different intercropping system. Significantly Superior RGR was noted in Ashwagandha + green gram (4.1) and Ashwagandha + niger (4:1) at 30-60 days; Ashwagandha + sesame (3:1) at 60-90 days; Ashwagandha + niger (3:1) and Ashwagandha + red gram (4:1) 90-120 days; Ashwagandha + red gram (3:1), at 120-150 days and Ashwagandha + sesame (3:1) 150 days – maturity stage. Thus, it could be said) that relative rate of accumulation of dry matter by Ashwagandha over its respective previously accumulated dry matter was unaffected by introducing intercrops in 3:1 and 4: 1 row proportion as compared to its sole stand.

NAR was significant affected by different Ashwagandha base intercropping system up to 90-120 days stage during both years of investigation.

It quite high at 30 DAS and from declined drastically till 90 DAS. After this, the NARs strongly raised till 120 DAS furthermore, the NARs rapidly declined till the maturity. Therefore, a typical sigmoid pattern of NAR was noted in Ashwagandha during its entire lifecycle. At very early growth stage (30 DAS), the NAR ranged from 14.29 to 15.76 mg/m^2/day due to different intercropping system with significant higher in Ashwagandha + sesame (3:1). On the basis of mean data, significantly higher NAR was recorded in Ashwagandha + green gram (4:1 and 3:1) at 30-60 days, Ashwagandha + green gram (3:1) and Ashwagandha + red gram (4:1) at 90 days and Ashwagandha + sesame (3:1) intercropping system at 90-120 days. The limit of NAR values was 1.54 to 1.80 mg/m^2/day, 1.19 to 1.32 mg/m^2/day, 1.25 to 1.33 mg/m^2/day, 1.53 to 1.85 mg/m^2/day and 1.13 to 1.32 mg/m^2/day and 60, 90, 120, 150 DAS and maturity stages, respectively between different treatment, but variation between most of intercrop and sole ashwagandha were found to be non-significant. Thus, it could be said that accumulation of photosynthate by the crop did not differ due its sole cropping versus different intercropping systems. The spatial row arrangement of Ashwagandha and intercrops in 3:1 and 4:1 row proportion also did not influence the NAR effectively.

The physiological parameters with respect to growth analyses like leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) are known as growth analysis parameters. In fact, efforts to correlate crop yields to canopy architecture began in the early 20th century with the development of growth analysis by British plant physiologists.

The periodical observations recorded on these growth analysis parameters of ashwagandha were found to be significantly (tables 1 and 2). However, amongst the cropping systems, ashwagandha intercropped with soybean resulted in significantly higher CGR and RGR during maturity stage of its growth. The maximum LAI was recorded in Ashwagandha with red gram and NAR in case of Ashwagandha with sesame. This might be owing

Table 1 : Leaf area index and Crop growth rate of ashwagandha under different intercropping systems (Pooled for 2 years).

Treatments	LAI						CGR (mg/m²/day)					
	30DAS	60DAS	90DAS	120DAS	150DAS	Maturity	0-30DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS-maturity
T_1- Ash. sole	1.44	2.80	4.00	5.18	5.08	4.99	2.93	3.40	4.23	4.57	5.13	6.73
T_2- Ash + red gram (3:1)	1.44	2.88	4.05	5.18	5.09	5.02	2.93	3.20	4.13	4.33	5.23	6.57
T_3- Ash+ green gram (3:1)	1.36	2.72	3.83	4.98	4.88	4.80	2.87	3.43	4.27	4.47	4.67	6.90
T_4- Aah + Soybean (3:1)	1.36	2.72	3.89	5.02	4.93	4.86	2.97	3.27	4.10	4.40	4.57	7.33
T_5- Ash + Sesame (3:1)	1.36	2.72	3.89	4.98	4.90	4.83	2.87	3.27	4.13	4.37	4.50	6.93
T_6- Ash + niger (3:1)	1.36	2.80	3.89	5.05	4.95	4.88	2.90	3.33	3.93	4.60	5.20	6.83
T_7-Ash + red gram (4:1)	1.36	2.72	3.89	5.02	4.91	4.83	2.90	3.23	4.20	4.45	4.57	7.17
T_8- Ash + green gram (4:1)	1.36	2.72	3.89	4.98	4.90	4.82	2.83	3.53	4.13	4.40	5.03	6.47
T_9 - Ash + soybean (4:1)	1.44	2.80	4.00	5.12	5.02	4.94	2.97	3.30	4.17	4.47	4.73	7.07
T_{10}- Ash + sesame (4:1)	1.36	2.72	3.89	5.02	4.93	4.85	2.87	3.33	4.10	4.53	5.00	6.90
T_{11}- Ash + niger (4:1)	1.44	2.88	4.05	5.18	5.09	5.01	2.83	3.50	4.20	4.40	4.60	7.17
SEm±	**0.01**	**0.02**	**0.05**	**0.05**	**0.01**	**0.02**	**0.009**	**0.026**	**0.046**	**0.033**	**0.042**	**0.038**
CD 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.20**	**0.08**	**0.13**	**0.09**	**0.12**	**0.10**

Table 2 : Net assimilation rate and Root yield of ashwagandha under different intercropping systems (Pooled for 2 years).

Treatments	NAR (mg/m²/day)						RGR (mg/m²/day)					
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS -maturity	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS-Maturity
T_1- Ash. Sole	14.80	1.66	1.26	15.54	1.405	1.14	149.23	25.67	17.07	11.97	9.20	9.70
T_2- Ash + red gram (3:1)	14.80	1.54	1.20	15.15	1.35	1.22	149.23	24.60	17.17	11.73	10.27	9.53
T_3- Ash+ green gram (3:1)	15.23	1.75	1.32	14.85	1.29	1.26	148.47	26.27	17.23	11.73	9.03	10.00
T_4- Aah + Soybean (3:1)	15.76	1.67	1.25	15.50	1.35	1.13	149.63	24.73	16.87	12.27	8.90	10.63
T_5- Ash + Sesame (3:1)	15.23	1.67	1.26	15.92	1.34	1.32	148.47	25.37	18.13	11.53	8.77	10.17
T_6- Ash + niger (3:1)	15.38	1.67	1.19	14.29	1.38	1.15	148.87	25.50	16.30	12.47	10.03	9.83
T_7- Ash + red gram (4:1)	15.38	1.65	1.29	15.54	1.25	1.25	148.87	24.97	17.40	12.63	8.80	10.37
T_8- Ash + green gram (4:1)	15.01	1.80	1.26	15.01	1.30	1.27	148.10	26.97	16.70	11.67	9.63	9.37
T_9 - Ash + soybean (4:1)	15.00	1.61	1.24	15.50	1.36	1.16	149.63	24.90	16.90	12.00	9.17	10.27
T_{10}- Ash + sesame (4:1)	15.23	1.70	1.25	15.38	1.4	1.25	148.47	25.73	16.90	12.23	9.67	9.93
T_{11}- Ash + niger (4:1)	14.29	1.68	1.22	14.65	1.35	1.23	148.10	26.80	17.07	11.97	8.87	10.30
SEm±	**0.07**	**0.018**	**0.012**	**0.04**	**0.04**	**0.02**	**0.28**	**0.13**	**0.07**	**0.13**	**0.06**	**0.07**
CD 5%	**0.20**	**0.05**	**0.03**	**0.11**	**NS**	**NS**	**NS**	**0.37**	**0.20**	**037**	**017**	**0.20**

Table 3 : Phenological and root yield of ashwagandha under different intercropping systems (Pooled for 2 years).

Treatments	Phenological parameter				Roots yield of ashwagandha (kg/ha)
	Days to germination	Days to flower initiation	Days to fruit Initiation	Days to physio-logical maturity	
T_1- Ash. Sole	14.05	94.65	112.80	173.90	518
T_2- Ash + red gram (3:1)	13.15	94.30	110.40	173.20	400
T_3- Ash+ green gram (3:1)	13.30	94.15	109.90	172.60	397
T_4- Aah + Soybean (3:1)	12.85	94.60	112.00	173.10	397
T_5- Ash + Sesame (3:1)	13.15	94.85	112.80	172.00	403
T_6- Ash + niger (3:1)	13.20	94.60	112.70	173.60	392
T_7- Ash + red gram (4:1)	13.00	94.25	113.00	172.40	423
T_8- Ash + green gram (4:1)	13.35	94.00	112.60	172.50	423
T_9 - Ash + soybean (4:1)	13.20	96.70	110.90	173.80	420
T_{10}- Ash + sesame (4:1)	13.35	94.90	112.40	173.70	430
T_{11}- Ash + niger (4:1)	13.35	94.30	112.90	173.30	425
SEm±	**0.94**	**1.17**	**0.99**	**1.78**	**7.61**
CD 5%	**NS**	**NS**	**NS**	**NS**	**21.97**

to the better availability and utilization of nutrients with presence of green gram and thereby effective conversation of multi nutrients at the site of photosynthesis into pigments (Sanjutha *et al*., 2008). In fact most favuorable soil condition might have produced maximum photosynthetic accumulation towards leaf biomass, because during initial stage, leaf is the most powerful sink than any other plant parts in most of the crops. In fact, live in is the factory for the conversion of solar energy into the chemical energy by the process of photosynthesis. Thus, the number of leaves/plant (surface area of leaves) justifies the ultimate final expression of CGR, RGR and NAR of the growing plants of ashwagandha. The diminishing response of other intercrops (pulses and oilseeds) as well as sole grown main crop ashwagandha may be due to variation in the nutrient composition and their release pattern in root zone for the actively growing ashwagandha plants. The best performance of green gram as intercrop over other might be owing to variation in it aggressiveness, compatibility with ashwagandha, differences in root and shoot growth, quantum of biological N-fixations, and nutrients absorption capacity under a given set of soil environment.

Moreover, the root and shoot growth of other intercrops like red gram, green gram, soybean, sesame and niger is quite different due to genetic architecture of parents and by virdure of their inheritance build up which did not provide the conductive soil environment for ashwagandha as provided by green gram. In fact, biomass production was found to be closely related to the amount of photo-synthetically action radiation (PAR) intercepted by different crop canopies In this experiment there were five intercrops of different crop canopies therefore amount of PAR intercepted by their intercrops was eventually different. Consequently the root and shoot growth of these intercrops was highly different.

Different phenological parameters of ashwagandha *viz*. days required completing germination, initiation of flowering and fruit formation, and to reach physiological maturity etc did not differ remarkably due to different intercropping systems (table 3). It completed germination within 12.85 to 14.05 days under different intercropping system on the basis of 2-years data. Similarly initiation of flowering observed in almost all intercropping system within 94.00 to 96.70 days, while fruit formation begin among all intercropping system within 109.9 113.0 days. The crop reached to physiological maturity stage at 172.0 to 173.9 days growth stage, since none of the intercrops grown with ashwagandha either in 3:1 row proportion or 4 :1 row proportion exerted any variable influence on growth and development of main crop, therefore there was no any possibility to change its phenological parameters.

In the present experiment, days taken to flower initiation, first fruit initiation and ultimately phonological maturity was observed non-significant under the influence different intercropping systems between ashwagandha (as main crop) and pulses and oilseeds (as intercrops). The data summarized in table 3 reveal that ashwagandha grown with pulses or oilseeds as intercrops resulted in 3-4 days earlier start of reproductive phase as compared to that when ashwagandha was grown as a sole crop.

Accordingly days to first fruit initiation and physiological maturity came two days earlier under ashwagandha with green gram (3:1 and 4:1), sesame (3:1), red gram (4:1) over single sown of ashwagandha. The beneficial impact of intercropping treatments upon these phenological parameters was almost equal. The phenological maturity under inter cropping systems reach in 172 days in Ashwagandha with sesame whereas when ashwagandha was grown alone, its maturity came late in 174 days. There was no any remarkable deviation in the phenological parameters of Ashwagandha when grown either in sole stand or intercropping stands. Similar results were corroborated with the finding of Lomte and Dabhade (1990), Singh *et al.* (1990), Souza *et al*. (2004).

Root yield

It is evident from the data that root yields of Ashwagandha significantly varied between different treatments in both years of investigation as well as for mean yields of both years. Based on 2 years mean data, sole crop Ashwagandha significantly produced higher root yields (518 kg/ha.) over all other intercropped stands producing root yields between 392 to 430 kg/ha. The variations in root yields between different intercropped stand were not significant, but intercropping of all associate crops with Ashwagandha in both 3:1 and 4:1 row proportions led to records consistently higher root yields than those obtained with respective associate crop in 3:1 row proportions. The root yields of Ashwagandha ranged between 420 to 430 kg/ha in 4:1 row proportions, while it ranged from 392 to 403 kg/ha in 3:1 row proportions.

The significantly higher values root yield under Ashwagandha grown sole might be owing to increased vegetative growth including leaves surface or photosynthetic area producing more photosynthetes for root growth and shoot development of ashwagandha. In comparison to other ten intercrops, green gram legume crop benefitted ashwagandha in several ways due to its better compatibility with the main crop. The variation in the development of roots and shoots of different intercrops is governed by their genetic architecture of parents. The parent results corroborate with those of Souza *et al*. (2004), Deohe *et al*. (2004), Shrivastava *et al*. (2004) and Lingaraja *et al*. (2008).

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