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RESEARCH ARTICLE

INFLUENCE OF PLANT GROWTH REGULATORS ON PHENOLOGY, GROWTH AND ROOT YIELD OF ASHWAGANDHA (*WITHANIA SOMNIFERA* (L.) DUNAL.)

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ABSTRACT

Research experiments were conducted to investigate the effect of growth regulators on phenology, growth and yield of Ashwagandha / Winter Cherry [*Withania somnifera* (L.) Dunal.) during late rainy seasons 2008-09 and 2009-10 at Research Farm, College of Horticulture, Mandsaur (M.P.) India. The results revealed that spray of IBA 100 $mg.l^{-1}$ effected maximum delay in floral initiation, 50 per cent flowering, 50 per cent fruiting; first fruit maturity and physiological maturity as compared to other growth regulators viz. MH, BA, Ethrel and water spray (control). There was no generalized specific trend found in LAI with respect to different growth regulators during crop growth stages SLA was maximum with IBA 150 $mg.l^{-1}$, while SLW was maximum with BA 30 $mg.l^{-1}$. MH 100 $mg.l^{-1}$ and BA 30 $mg.l^{-1}$ were found equally effective and the best treatments in increasing RGR and CGR during flowering (60-90DAS), while IBA 50$mg.l^{-1}$ was the best responding spray for RGR and CGR enhancement during fruiting to physiological maturity at (90-150 DAS). Growth regulators did not produce any definite trend in LWR and LAR but MH 100 $mg.l^{-1}$ is the best in increasing LWR and LAR in general. Spray of BA 10 $mg.l^{-1}$and IBA 100 $mg.l^{-1}$increased leaf persistence (LAD) in the crop, while that of BA 40 $mg.l^{-1}$ and MH 100 $mg.l^{-1}$ individually got maximum BMD. IBA 50 $mg.l^{-1}$ produced maximum plant height (41.27 cm) while MH 250 $mg.l^{-1}$ was highly effective in suppressing plant height (31.40 cm) as compared to other treatments. Sprays of IBA 100/150 $mg.l^{-1}$ and Ethrel 100/150 $mg.l^{-1}$ individually were very effective in increasing root length while BA spray suppressed the root length. IBA 100$mg.l^{-1}$ and BA 40 mg. l^{-1} were found equally effective in producing the maximum root yield (11.45 q/ha) which was 37.45% higher than control.

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INTRODUCTION

Asgandh / Ashwagandha (Winter Cherry) is one of the most important medicinal crops commercially cultivated in India . Ashwagandha [*Withania somnifera* (L.) Dunal.] belongs to family Solanceae. It is commercially cultivated in western Madhya Pradesh (Mandsaur, Neemuch) and eastern Rajasthan. It is cultivated in 10000-15000 hectare area to produce 2500-3500 tonnes with average productivity (6-7 q/ha.) (Chadda, 2001). Ashwagandha is late sown rainy season crop and is ready for harvest in 150-170 days after sowing. There is a good demand of root of Ashwagandha, which is also called Indian Ginseng owing to its use as sex tonic. Leaves and seeds are also valued owing to their medicinal properties. The roots and leaves of this plant contain many alkaloids and withanolides (Chadda, 2001). Root is main medicinally important plant part which is used to increase vigour, vitality and to cure diseases like impotency, cough, rheumatism, fever, ulcers and leucoderma, dropsy, stomach and lung inflammation, skin diseases and several female disorders. It is also an ingredient of medicament prescribed for curing disability and sexual weakness in male.

Of the several factors affecting root yield of Asgandh, time of sowing, seed rate, nutrient status of soil are the important factors. The crop sown on 7 August (at Mandsaur) gave significantly higher root yield Kahar *et al*. (1991). Earlier and latter sown fields showed gradual reduction in root yield kahar *et al*. (1991). Broadcasting method of sowing was superior to line sowing in respect of dry root yield. Response of plant densities on dry root yield of Asgandh indicated that 6.6 lakh/ha plants followed by 3.3 lakh/ha recorded highest dry

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root yield over lower plant population (Nigam *et al.,1984*). In another study, the response of plant density was found up to 15-lakh plants/ha (Nigam, *et al*., 1985). Response of fertilizers was tested for dry root yield in Asgandh. The study indicated that increasing levels of fertilizers had no effect on the dry root yield of Asgandh on account of either the genotype or inadequate levels of fertilizers tried (Nigam *et al*., 1984, 1985). This under shrub is at present cultivated over very poor marginal soils with almost no fertilizer inputs. Natural selection has favoured genotypes adopted for low fertility.

Besides various factors narrated above, growth regulators / hormones play important role in seed germination, cell enlargement, cell division, and root formation, retardation of plant height and thereby influencing of growth, productivity and quality of many important horticultural crops. Differential response of various growth regulators in affecting growth, differentiation, development and finally productivity of different crops particularly horticultural crops like coriander, fennel, fenugreek *etc* has been studied thoroughly. But in Ashwagandha practically meager work has been done to study the effect of plant hormones and growth regulators on growth, development, productivity and root quality. Hence, an experiment will be conducted to study the effect of plant growth regulators on phenology, growth and yield of Ashwgandha (*Withania somnifera* (L.) Dunal.

MATERIALS AND METHODS

Experimental site

The experiment was laid out at the "Bahadari farm" K.N.K. College of Horticulture, Mandsaur (M.P.) India during "Kharif" seasons of 2008-09 and 2009-10. Mandsaur is situated at North latitude of 23.450 to 24.130 and 74.440 to 75.180 East longitudes and an altitude of 435.02 meters above mean sea level. This region falls under agro climatic zone no.10 (Malwa Plateau) of the state.

Climatic conditions

Mandsaur belongs to sub-tropical and semi-arid climatic conditions having a temperature range of minimum 5oC and maximum 44oC in winter and summer respectively. In this area maximum rainfall is received during mid June to September. The average rainfall is 544.05 mm. South-West monsoon is responsible for major part of annual precipitation. Meteorological data recorded during the period of investigation are presented in Table 1.

Soil characteristics of the experimental site

To ascertain physico-chemical characteristics of the soil during the year of study, soil samples from 0-15 cm depth were taken from different spots of the experimental field before application of fertilizer. Soil analysis report presented in (Table 2), showed that the soil was light black loamy in texture, with low in availability of nitrogen, low in phosphorus and high in potassium status.

Table 1. Average Meteorological data during the period of investigation from 25 August to15 February during 2008-09

Standard Week No.	Duration	Average weekly Temperature (^{0}C)		Soil Temperature (^{0}C)	Mean RH (%)	Weekly Rainfall (mm)
		Min.	Max.			
35	25 Aug- 31 Aug.	22.24	27.74	27.41	88.85	Nil
36	01 Sep-07Sep	24.15	30.88	26.15	80.71	23
37	08 Sep-14 Sep	23.49	28.23	25.63	85	20
38	15 Sep-21 Sep	23.24	29.27	25.47	77.28	11
39	22 Sep -28 Sep	23.13	30.32	25.6	76.57	Nil
40	29 Sep -05 Oct	23.63	31.88	25.77	57.71	Nil
41	06 Oct –12 Oct	24.31	34.25	25.48	49.71	19
42	13 Oct –19 Oct	22.3	31.41	25.5	46.57	Nil
43	20 Oct –26 Oct	21.33	29.51	25.57	50.43	120
44	27 Oct-02 Nov	20.07	29.6	25.4	37.71	Nil
45	03 Nov –09Nov	19.22	29.81	25.65	29.85	Nil
46	10 Nov –16Nov	17.94	28.15	25.27	41.43	Nil
47	17 Nov –23Nov	13.4	24.14	22.45	61.85	22
48	24 Nov –30Nov	8.6	23.67	22.37	49	Nil
49	01 Dec -07 Dec	7.5	24.38	23.05	41.71	Nil
50	08 Dec -14 Dec	9.18	27.17	24.59	54.71	Nil
51	15 Dec -21 Dec	8.37	25.96	25.52	59.71	Nil
52	22 Dec -28 Dec	8.38	22.21	25.51	58.28	Nil
01	29 Dec-04 Jan	7.5	24.34	25.08	55.57	Nil
02	05 Jan –11 Jan	6.5	20.3	24.72	60.85	Nil
03	12 Jan –18 Jan	10.5	21	25.05	47.42	Nil
04	19 Jan –25 Jan	12.74	25.41	25.2	46.28	Nil
05	26 Jan-01 Feb	10.11	26.07	25.04	43.14	Nil
06	02 Feb –08 Feb	12.00	26.86	25.41	51.28	Nil
07	09 Feb –15 Feb	13.07	28.6	24.98	45.42	Nil

Experimental Methods

Experimental details

The experiment were conducted in a randomized block design with 20 treatments (various concentrations of plant growth regulators) replicated thrice. High yielding variety (Jawahar Asgnadh -134) of *W. somnifera* in India was taken as experimental material. Row to row and plant to plant distance were 30 cm and 3.70 cm respectively. Date of sowing and harvesting were 28 August and 12 Feb respectively.

Treatments- Plant growth regulator levels:(19 + Control)

(i) IBA-50 $mg.l^{-1}$
(ii) IBA-100 $mg.l^{-1}1$
(iii) IBA-150 $mg.l^{-1}$
(iv) IBA-200 $mg.l^{-1}$

(v) IBA-250 $mg.l^{-1}$
(vi) Ethrel -100 $mg.l^{-1}$
(vii) Ethrel -150 $mg.l^{-1}$
(viii) Ethrel -200 $mg.l^{-1}$
(ix) Ethrel -250 $mg.l^{-1}$
(x) Ethrel -300 $mg.l^{-1}$
(xi) BA -10 $mg.l^{-1}$
(xii) BA -20 $mg.l^{-1}$
(xiii) BA -30 $mg.l^{-1}$
(xiv) BA -40 $mg.l^{-1}$
(xv) BA -50 $mg.l^{-1}$
(xvi) MH-100 $mg.l^{-1}$
(xvii) MH-150 $mg.l^{-1}$
(xviii) MH-200 $mg.l^{-1}$
(xix) MH-250 $mg.l^{-1}$
(Xx) Control-water spray

Cultural operations

The field was properly ploughed by disc harrow and then pulverized and leveled properly. The calculated quantities of Nitrogen (N) Phosphorus (P_2O_5) and Potash (K_2O) were applied to the all plots as basal dose. The sources of nitrogen, phosphorus and potash were Urea (46% N_2), Single super phosphate (16 % P_2O_5) and Muriate of potash (60% K_2O).

Variety Characteristics

Asgandh variety- "Jawahar Asgandh – 134" developed at JNKVV, K.N.K. College of Horticulture, Mandsaur (M.P.), is suitable for growing, both for early sowing and as Kharif crop. The plant type- Annual, Erect, biparous branching on main stem at 25-30 cm height, Root colour- Brown hairy leaves of dark green colour, Berries colour- Yellow, Root smooth-Cylindrical with few root hairs and high starch content, Maturity-175±15 days, Dry root yield-8-10 Q/ha, Seed yield – 5-6 q/ha, Alkaloids content – 0.6%

Seed, seed rate and sowing

Sowing was done at the rate of 10 kg/ha. The source of seed is All India Network Programming on Medicinal and Aromatic Plants, College of Horticulture, Mandsaur (M.P.). The pure, healthy, disease and insect free vigorous and good quality seed Asgandh were used for sowing. Prior to sowing, seed were cleaned and treated with carbandazim (2gm/kg seeds) and then sown in furrows opened at 30cm row spacing and covered with soil properly.

Thinning

Two thinning were done first at 30 DAS to remove the excess plants and for maintaining plant to plant spacing of 3.70 cm and plant populations (9 lacks plants/ ha).

Weeding and hoeing

After date of sowing two weeding / hoeing were done manually, first at 20 DAS, and second 40 DAS, to control the seasonal weeds.

Irrigation

Single irrigation was given just after sowing the seed proper germination and establishment of the crop seedlings.

Plant Protection Measures

In order to safe guard the plants damping off and other disease, fungicide- Mancozeb and Metalaxyl combined (2.5g/L) was sprayed on at 25 DAS and 50DAS.

Crop studies conducted

Sampling

Sampling was done at the fixed interval of 30days after sowing on leaf area, leaf biomass and shoot biomass for computation of data for physiological parameters. Five plants were randomly selected in each replication, for partitioning into leaf and stem dry matter and measurement of leaf area for growth analysis.

Observations

Phenology

The phenology of cultivar Jawahar Asgandh -134 was noted with regard to:

1. Days to germination.
2. Days to floral initiation.
3. Days to 50% flowering.
4. Days to 50% fruiting.
5. Days to first fruit maturation.
6. Days to physiological maturity.

Plant growth analysis

Growth analytical parameters like Leaf Area Index (LAI), Specific leaf area (SLA), Specific leaf weight (SLW), Relative Growth Rate (RGR), Crop Growth rate (CGR), Leaf weight ratio (LWR), Leaf Area Ratio (LAR), Leaf area duration (LAD) and Biomass duration (BMD) were calculated as per formulae given by Gardener *et al*., 1985, Gardner *et al*. 1985, Gardner *et al*., 1985, Beadle, 1985, Gardner *et al*., 1985, (Beadle, 1952, Gardner *et al*., 1985, Watson, 1952,and Mc Collum, 1978 respectively.

Statistical Analysis

Analysis of different variables was carried out to know the degree of variation amongst all the treatments. The data collected at different growth stages were analyzed for completely randomized design by the method given by Fisher(1967).

RESULTS AND DISCUSSION

Phenological characters

Phenology of *Withania somnifera* when studied in late Kharif season (sown on 28th Aug, 2008) in vertisol soil of Mandsaur gave remarkable results with reference to foliar sprays of various growth regulators at 30, 60 and 80 DAS. Various growth regulators sprays differentially affected days to taken to floral initiation, 50% flowering, 50% fruiting; first fruit maturity and physiological maturity. Seed germination took 7 to 10 days. Days taken to floral initiation took 65 to 68 DAS (days after sowing) in Ashwagandha with different kind and concentrations of growth regulators. IBA, Ethrel and MH delayed flower initiation while BA promotes early floral initiation. IBA 100 and Ethrel 300 mg.l-1 delayed flowering maximum up to 68 DAS as compared to control (water spray). Role of Ethylene and MH in delaying flowering is well established fact while exogenous application of auxins inhibits flower initiation in short day plants (Prasad and Kumar 2005). These results also support the findings of Prasad and Kumar (2005) regarding role of benzyl adenine (BA) in inducing early flowering. Delayed flowering in response to Ethrel application is also reported by Namika *et al*. (2002) in Chrysanthemum cultivars. Days to 50% flowering and 50% fruiting also delayed due to IBA and Ethrel, while BA and MH promoted early flowering. IBA 100 $mg.l^{-1}$and Ethrel 250 $mg.l^{-1}$delayed 50% flowering to maximum 79 and 80 DAS respectively as compared to control and BA (75DAS). These results are attributed to delay flowering induced by these hormones. First fruit maturity showed different pattern due to growth regulators. First fruit maturity prolonged maximum (139 DAS) when IBA sprayed 100 $mg.l^{-1}$, BA 30 $mg.l^{-1}$and MH 100 $mg.l^{-1}$. Earliest first fruit maturity was found with Ethrel 250 $mg.l^{-1}$as compared to control (132 -133 days). Role of Ethrel (Ethylene) in enhancing rate of fruit maturity is also supported by Prasad and Kumar (2005). Physiological maturity is the development stage after which non-significant increment in biomass occurs in plants. It is a cumulative effect of internal and external growth regulators in floral initiation, leaf senescence and plant ageing. Physiological maturity, if prolonged in *Withania somnifera*, the crop produces more biomass accumulation in plant and may increases the economic productivity of root. Maximum delay in physiological maturity (159-160 days) was achieved due to IBA 150 $mg.l^{-1}$, Ethrel (100 $mg.l^{-1}$and MH 150 $mg.l^{-1}$, while earliest physiological maturity occurred when sprays of BA 10 $mg.l^{-1}$or water was applied.

Physiological plant growth analysis

Efficient use of captured solar energy is the key factor controlling the productivity of any crop. Plant growth comprises the conversion of substrate molecules into specific component and subsequent utilization and its storage in the plant. Higher yield per unit of substrate can be achieved only by the production of energetically cheaper storage organs. Maintenance of storage organs (sink) during their development also consumes 6 to 25% of total substrate for their growth (Penning Devries *et al.* 1983). The realization of maximum yield potential of any crop can only be achieved by designing a suitable plant type having fast growing habit with a canopy architecture well suited to utilize maximum solar radiation for realizing the maximum potential productivity of any crop. The growth analysis is a relatively simple, most easy and practical method of assessing net photosynthetic production and its partitioning into various plant parts including economic sink. Improvement in growth and development characteristics of plant due to type and concentration of various growth regulators application is well known in different crops. In the present investigation, some very important and useful results have been obtained. These results are helpful in selecting physiological indices of Ashwagandha attributing to the root, alkaloid and Withanolides productivity. This will be helpful in future breeding programmes.

As leaf is the organ of photosynthesis; the surface area of leaves per plant should be an important determinant in production of photosynthate as suggested by Watson (1947). It is known that photosynthetic efficiency depends on leaf area, chlorophyll content and the gas exchange. Correlation between leaf and yield (Alluwar and Deotale, 1991) suggests the importance of chlorophyll and leaf area in determining yield. The leaf area index (LAI) describes the functional size of assimilatory apparatus of plant stand and served as a primary value for calculation of other parameters (Watson, 1947, 1952). The leaf area of crop stand and its increase has a direct bearing on amount of solar energy intercepted by canopy and represents the productive capacity of a crop.

LAI

LAI in Ashwagandha increased with age up to 90 DAS and there after gradually decreased till physiological maturity. At 30 DAS, LAI was apparently same as treatment of growth regulators were done at 30, 60 and 80 DAS. But at 60, 90, 120 and 150 DAS, LAI varied significantly due to various type and strength of growth regulators. At 60 DAS (just before flowering), maximum realization of LAI (2.62-2.49) was achieved by IBA 150 $mg.l^{-1}$, Ethrel 100 $mg.l^{-1}$, BA 10/20 $mg.l^{-1}$, MH 100/150/250 $mg.l^{-1}$. At 90 DAS MH 100 $mg.l^{-1}$ followed by Ethrel 250/300 $mg.l^{-1}$produced maximum LAI (3.51-3.24). After that LAI decreased gradually at 120 and 150 DAS. At 120 DAS, maximum LAI (2.71) was recorded with IBA 250 $mg.l^{-1}$, while minimum LAI (2.38-2.34) was recorded with Ethrel 250 $mg.l^{-1}$and BA 10/40 $mg.l^{-1}$. The least LAI was found with water spray (control) during all stages of growth and development. Photo synthetically active area (LAI) was reported maximum under spray of IBA and MH and minimum with Ethrel and BA. These may possibly be due to the fact that auxins (IBA), delays flowering and senescence at the same time, while Ethrel (Ethylene) promotes senescence of leaf. This role of auxins may responsible for increased leaf area index by IBA and decreased LAI by Ethrel (Prasad and Kumar 2005)

SLA

SLA differed due to various treatments of growth regulators during all the stages of growth except during 60-90 DAS. At 30-60 DAS, maximum SLA was found with MH 150 $mg.l^{-1}$. At 90-120 DAS, maximum leafiness (SLA) was found when IBA 250 $mg.l^{-1}$ or BA 20 $mg.l^{-1}$was sprayed. At 120-150 DAS, IBA 150 $mg.l^{-1}$produced maximum leafiness (SLA) in *Withania* crop. Water spray (control) produced significantly less leafiness during all growth stages.

SLW

SLW, the indicator of thickness of leaf, varied due to growth regulators and their concentrations during all stages except at vegetative stage (30-60 DAS). Increasing SLW with advancement growth stages was remarkably seen in all the treatments that mean leaf thickness increases with crop age is the general feature of the crop. Maximum SLW (92.09-80.91 g/m^2) was found with BA 30 $mg.l^{-1}$and Ethrel 100 $mg.l^{-1}$during 60-90 DAS. BA 30 $mg.l^{-1}$produced maximum SLA of 121.67 and 110.86 g/m^2 during 90-120 DAS q/ha 120-150 DAS respectively. This may be due to the reason that BA delays leaf senescence and thereby causing leaf thickening and persistence depicted in the form highest SLW, which is the ratio of leaf biomass to leaf area. On the other hand, IBA and MH behaved in opposite way and produces maximum SLA (*i.e.* more thinly leaves) for intercepting maximum sun light.

RGR

RGR is the indicator of biomass increase with respect to advancement of crop age. RGR generally increased up to 60-90 DAS and there after decreased gradually during advancement of age from 90-120 and 120-150 DAS in all the treatments. RGR differed significantly due to various treatments of growth regulator except during 30-60 DAS (vegetative phase). Maximum RGR (0.020-0.018 g/day) was attained by application MH 100 $mg.l^{-1}$, BA 30/40 $mg.l^{-1}$and water at 60-90 DAS of crop age. At 90-120 DAS, maximum RGR (0.007-0.005 g/day) was found with IBA 50/100/150/200/250 $mg.l^{-1}$, Ethrel 100/200/250 and water, while at 120-150 DAS, IBA 50/100/150/200/250 $mg.l^{-1}$, Ethrel 150-30 $mg.l^{-1}$, BA 50 $mg.l^{-1}$and water showed maximum RGR (0.005-0.003g/day)

CGR

Increasing pattern of crop growth rate was noted up 60-90 DAS stage and decreased thereafter with advancement of crop age in general. Various growth regulator sprays significantly affected CGR during all stages of growth in Ashwagandha. At 30-60 DAS, maximum CGR ranging from (8.20-6.61 g/m^2/day) was recorded with BA 10-50 $mg.l^{-1}$, Ethrel 100-300 $mg.l^{-1}$, IBA 100/250 $mg.l^{-1}$, MH 200/250 $mg.l^{-1}$and water, while minimum CGR was found with MH 150 $mg.l^{-1}$. At 60-90 DAS, maximum CGR was found with BA 30/40 $mg.l^{-1}$and MH 100 $mg.l^{-1}$. At 90-120 DAS, IBA 50-250 $mg.l^{-1}$recorded maximum CGR (11.80-3.20 g/m^2/day) were as at 120-150 DAS, IBA 50-250 $mg.l^{-1}$and BA 10/30/40 $mg.l^{-1}$ noted maximum CGR. Maximum CGR during active crop growth 60-120 DAS was reported with IBA and BA owing to their role in delaying senescence.

LWR

LWR also increased up to 60-90 DAS, but drastically decreased thereafter upto 120-150 DAS in Ashwagandha. Various growth regulators produced significant various in LWR in all the stage of Ashwagandha. At 30-60 DAS, maximum LWR (0.0096-0.0082) was found with IBA 150 $mg.l^{-1}$, MH 100/150 $mg.l^{-1}$. At 90-120 DAS, MH 150 $mg.l^{-1}$and IBA 200/250 $mg.l^{-1}$recorded maximum LWR. At 60-90 DAS, MH 150 $mg.l^{-1}$noted maximum LWR. At 120-150 DAS, MH 150 $mg.l^{-1}$and BA 10 $mg.l^{-1}$individually attained maximum LWR.

LAR

LAR represents leafiness of crop in relation to biomass production. Decreasing patters of LAR with advancement of crop age is the remarkable feature noted in Ashwagandha crop. Various growth regulators affected LAR significantly at all growth stages. At 30-60DAS, 60-90 DAS, and at physiological maturity (120-150 DAS) maximum LAR was found with spray of MH 250 $mg.l^{-1}$. At 90-120 DAS, spray of BA 30 $mg.l^{-1}$gave maximum LAR.

LAD

LAD increased up to 60-90 DAS and gradually increased there after up to 120-150 DAS. Treatments of growth regulators affected LAD significantly in all stages of growth. During 30-60 DAS, maximum LAD (41.27-39.29 m^2 day) was realized by spray of BA 10/20 $mg.l^{-1}$, MH 100/150/250 $mg.l^{-1}$, water, Ethrel 100/150 $mg.l^{-1}$and IBA 150/250 $mg.l^{-1}$. At next stage (60-90 DAS), spray of MH 100 $mg.l^{-1}$, Ethrel 200 $mg.l^{-1}$and BA 10 $mg.l^{-1}$gave maximum LAD (90.45-87.21m^2 day). At 90-120 DAS, BA 10 $mg.l^{-1}$gave maximum LAD (84.74 m^2 day). At 120-150 DAS, maximum LAD (72.27-67.23 m^2 day) was given by BA 10/40 $mg.l^{-1}$and IBA 100/150/250 $mg.l^{-1}$.

BMD

BMD increased continuously from 30 to 150 DAS in *Withania*. There was a significant variation in BMD due to various growth regulators during all stages except at 30-60 DAS. At 60-90 DAS, maximum BMD was noted with BA 40/30 $mg.l^{-1}$and MH 100 $mg.l^{-1}$BA 40 $mg.l^{-1}$and MH 100 $mg.l^{-1}$maximum BMD was recorded with both during 90-120 and 120-150 DAS in *Withania*. IBA and BA are main growth regulators in delaying senescence, flowering, fruiting, causing maximum accumulation of photosynthate and thereby growth and development seen in the form of increasing photosynthetic efficiency of crop as shown in increased parameter of growth like LAI, SLW, CGR, RGR, LAD and BMD.

Morphological yield attributes and yield

Plant height (cm)

Plant height increased upto 150 DAS. Various growth regulators significantly affected plant height during all stages of growth from 60 DAS onwards. IBA sprays were highly effective in increasing plant height of Withania somnifera. IBA 50 mg.l^{-1}spray produced maximum plant height (41.27cm). Increasing IBA dose decreased plant height .Ethrel and Maleic hydrazide were effective in suppressing plant height. The minimum plant height (31.40) was found with MH 250 mg.l^{-1}.These results are also supported by Barath Kumar *et al*., (2001) in *Withania somnifera*. Retarding effect of Ethrel and MH on plant height was also reported by Turk *et al*. (2002), Gautam *et al*., (2003), Das *et al*., (1972) and Chauhan *et al*., (1972).

Number of nodes per plant

Number of nodes increased gradually with advancement of crop age. Growth regulators spray did not influence number of nodes in Ashwagandha crop at any stage of crop growth from 30 DAS to 150 DAS.

Number of branches per plant

Number of branches was not affected due to spray of various growth regulators in Ashwagandha at any stage of plant growth and development.

Number of leaves per plant

Number of leaves was not affected due to growth regulators at any stage of crop growth.

Root length (cm)

Root length showed increasing pattern with advancement of crop age in *Withania*. IBA 100/150 mg.l^{-1}and Ethrel 100/150 mg.l^{-1}individually were highly effective in increasing root length during all stages of growth and development of the crop from 60-150 DAS. BA 10-40 mg.l^{-1}gave minimum root length. This showed that active root growth increases after 60 DAS and upto 150 DAS. These findings corroborates with the findings of Barath Kumar *et al*. (2001) and Prasad and Kumar (2005).

Root Yield (q/ha)

The maximum root biomass productivity (11.45-10.90 q/ha) was effected due to IBA 100/250 mg.l^{-1}and BA 40 mg.l^{-1}. However, the minimum root biomass productivity (6.93-8.02 q/ha) was found with BA 10/30/50 mg.l-1 and Ethrel 200/300 mg.l^{-1}. Since, root is commercially main economic part of Withania and root biomass increase was promoted by IBA 100 mg.l^{-1}and BA 40 mg.l^{-1}, hence it is the most remarkable finding in achieving maximum productivity and monetary gain to farmers. These findings may also due to the reason that IBA and BA not only promotes growth by decreasing leaf senescence and ageing, but also delay flowering. This makes crop to increase accumulation of assimilates in them that partitioned efficiently to accumulate in economic sink as well (*i.e*. root). Hence, maximum root biomass productivity, the most important commercial parameter of crop productivity, is the function of biomass accumulation (*i.e*. total biomass productivity) and efficient partitioning of biomass towards roots. These findings of increased root productivity in response to IBA sprays are in contrary to the findings of Kumar *et al*. (2001). In a nutshell it is concluded from the present investigation that IBA 100 mg.l^{-1}or BA 40 mg.l^{-1}were the best treatments in achieving optimum growth as well as the best root yield (11.45 q/ha) *via* efficient partitioning of assimilates towards economics sinks (roots). There is a need to investigate good number of germplasm under different sowing dates and soils so as to have confirmed the findings of the present experiment. Further there is a need to get interaction effects of IBA, BA and MH with other inputs on *Withania somnifera* for the better partitioning of biomass, alkaloid and withanolides towards roots and thereby to maximize not only the root yield. In this way, maximum profit could be earned in future era of quality conscious global markets.

Table 2. Effect of different plant growth regulators on phenological characters of *Withania somnifera*

Treatment	Days to germina-tion	Days to floral initiation	Days to 50% flowering	Days to 50% fruiting	Days to first fruit maturity	Physiological maturity
T_1 –IBA 50 mg.l-1	10	66	75	105*	135	152
T_2-IBA 100 mg.l-1	8	68	79	109	138	160
T_3 -IBA 150 mg.l-1	8	67	79	107	139	156
T_4-IBA 200 mg.l-1	8	67	79	110	134	155
T_5-IBA 250 mg.l-1	8	66	77	108	137	159
T_6-Ethrel 100mg.l-1	9	67	77	107	136	160
T_7-Ethrel 150mg.l-1	10	67	77	109	135	158
T_8- Ethrel 200mg.l-1	8	67	77	105	134	156
T_9- Ethrel 250 mg.l-1	8	67	80	108	132	154
T_{10}- Ethrel 300 mg.l-1	8	68	78	107	135	152
T_{11}- BA 10 mg.l-1	9	66	76	105	136	151
T_{12}- BA 20 mg.l-1	8	64	76	108	137	153
T_{13}- BA 30 mg.l-1	8	64	77	107	138	154
T_{14}- BA 40 mg.l-1	8	63	75	105	135	151
T_{15}- BA 50 mg.l-1	8	63	75	106	136	155
T_{16}- MH 100 mg.l-1	7	66	76	105	138	157
T_{17}- MH 150 mg.l-1	9	66	78	109	136	159
T_{18}-MH 200 mg.l-1	8	67	77	107	137	156
T_{19}-MH-250 mg.l-1	8	67	77	106	136	155
T_{20}-Controlwaterspray	8	63	75	102	133	151
SEM ±	0.61	0.59	0.59	0.59	0.60	0.57
CD at 5%	NS	1.60	1.64	1.64	1.66	1.56

Table 3. Effect of different plant growth regulators on LAI in Withania *somnifera* at various growth stages

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1 –IBA 50 mg.l-1	0.13	2.34	2.30	1.57	1.50
T_2-IBA 100 mg.l-1	0.13	2.41	2.86	2.37	2.13
T_3 -IBA 150 mg.l-1	0.13	2.61	2.83	2.39	2.10
T_4-IBA 200 mg.l-1	0.14	2.40	3.02	1.83	1.75
T_5-IBA 250 mg.l-1	0.14	2.48	2.75	2.71	1.77
T_6-Ethrel 100 mg.l-1	0.14	2.49	3.01	1.67	1.67
T_7-Ethrel 150 mg.l-1	0.13	2.54	2.97	1.90	1.61
T_8- Ethrel 200 mg.l-1	0.14	2.59	3.16	1.78	1.64
T_9- Ethrel 250 mg.l-1	0.14	2.31	3.29	2.38	1.40
T_{10}- Ethrel 300 mg.l-1	0.14	2.20	3.24	1.59	1.51
T_{11}- BA 10 mg.l-1	0.13	2.62	3.20	2.45	2.36
T_{12}- BA 20 mg.l-1	0.12	2.57	3.12	2.12	2.08
T_{13}- BA 30 mg.l-1	0.12	2.42	2.91	1.83	1.84
T_{14}- BA 40 mg.l-1	0.13	2.26	2.84	2.45	2.34
T_{15}- BA 50 mg.l-1	0.14	2.17	3.00	1.82	1.74
T_{16}- MH 100 mg.l-1	0.13	2.52	3.51	1.86	1.53
T_{17}- MH 150 mg.l-1	0.12	2.62	3.03	2.11	1.74
T_{18}-MH 200 mg.l-1	0.12	2.40	2.88	1.74	1.63
T_{19}-MH-250 mg.l-1	0.12	2.51	3.15	1.74	1.55
T_{20}-Control water spray	0.13	2.18	2.22	1.46	1.52
SEM ±	0.01	0.05	0.10	0.09	0.09
CD at 5%	NS	0.13	0.29	0.25	0.25

Table 4. Effect of different plant growth regulators on SLA in *Withania somnifera* at various growth stages

Treatment	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	0.0122	0.0125	0.0105	0.0090
T_2-IBA 100 mg.l-1	0.0095	0.0140	0.0171	0.0142
T_3 -IBA 150 mg.l-1	0.0114	0.0139	0.0157	0.0136
T_4-IBA 200 mg.l-1	0.0098	0.0145	0.0152	0.0146
T_5-IBA 250 mg.l-1	0.0106	0.0142	0.0213	0.0199
T_6-Ethrel 100 mg.l-1	0.0094	0.0127	0.0114	0.0097
T_7-Ethrel 150 mg.l-1	0.0104	0.0138	0.0121	0.0116
T_8- Ethrel 200 mg.l-1	0.0087	0.0131	0.0132	0.0112
T_9- Ethrel 250 mg.l-1	0.0099	0.0133	0.0124	0.0132
T_{10}- Ethrel 300 mg.l-1	0.0095	0.0139	0.0111	0.0111
T_{11}- BA 10 mg.l-1	0.0121	0.0148	0.0108	0.0105
T_{12}- BA 20 mg.l-1	0.0095	0.0173	0.0180	0.0121
T_{13}- BA 30 mg.l-1	0.0102	0.0118	0.0097	0.0085
T_{14}- BA 40 mg.l-1	0.0097	0.0127	0.0161	0.0146
T_{15}- BA 50 mg.l-1	0.0105	0.0144	0.0109	0.0096
T_{16}- MH 100 mg.l-1	0.0115	0.0177	0.0146	0.0110
T_{17}- MH 150 mg.l-1	0.0127	0.0169	0.0144	0.0127
T_{18}-MH 200 mg.l-1	0.0115	0.0147	0.0121	0.0112
T_{19}-MH-250 mg.l-1	0.0102	0.0136	0.0130	0.0111
T_{20}-Control water spray	0.0081	0.0124	0.0103	0.0099
SEM ±	0.0006	0.00013	0.0014	0.0008
CD at 5%	0.0001	NS	0.0038	0.0023

Table 5. Effect of different plant growth regulators on LAR in *Withania somnifera* at various growth stages

Treatment	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	4.55	2.46	1.76	0.88
T_2-IBA 100 mg.l-1	3.81	1.82	1.38	1.12
T_3 -IBA 150 mg.l-1	3.15	2.29	1.74	0.76
T_4-IBA 200 mg.l-1	4.34	1.78	1.35	0.65
T_5-IBA 250 mg.l-1	3.58	2.02	1.36	1.27
T_6-Ethrel 100 mg.l-1	4.30	2.74	1.19	1.13
T_7-Ethrel 150 mg.l-1	3.58	1.69	1.36	1.36
T_8- Ethrel 200 mg.l-1	4.14	1.98	1.20	1.10
T_9- Ethrel 250 mg.l-1	3.96	1.58	1.39	1.15
T_{10}- Ethrel 300 mg.l-1	4.26	1.44	2.13	0.66
T_{11}- BA 10 mg.l-1	3.47	2.72	2.04	0.70
T_{12}- BA 20 mg.l-1	4.43	2.68	1.92	0.86
T_{13}- BA 30 mg.l-1	3.72	2.98	3.10	0.79
T_{14}- BA 40 mg.l-1	4.05	3.58	3.64	1.51
T_{15}- BA 50 mg.l-1	4.59	2.93	2.14	1.10
T_{16}- MH 100 mg.l-1	3.35	3.12	2.16	0.76
T_{17}- MH 150 mg.l-1	2.76	2.10	1.45	0.70
T_{18}-MH 200 mg.l-1	3.84	1.76	1.68	0.77
T_{19}-MH-250 mg.l-1	4.30	4.22	1.87	0.84
T_{20}-Control water spray	3.25	1.89	1.80	1.00
SEM ±	0.33	0.34	0.25	0.20
CD at 5%	0.92	0.94	0.68	0.55

Table 6. Effect of different plant growth regulators on SLW in *Withania somnifera* at various growth stages

Treatment	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	82.61	80.64	79.44	114.04
T_2-IBA 100 mg.l-1	135.06	71.90	71.13	82.24
T_3 -IBA 150 mg.l-1	116.57	74.68	75.34	84.45
T_4-IBA 200 mg.l-1	121.28	70.96	67.75	70.00
T_5-IBA 250 mg.l-1	116.62	72.67	55.89	65.24
T_6-Ethrel 100 mg.l-1	139.49	80.91	88.17	107.50
T_7-Ethrel 150 mg.l-1	129.93	74.46	82.78	87.69
T_8- Ethrel 200 mg.l-1	146.00	77.37	76.34	90.76
T_9- Ethrel 250 mg.l-1	129.33	76.11	81.04	76.73
T_{10}- Ethrel 300 mg.l-1	141.64	73.38	97.56	98.54
T_{11}- BA 10 mg.l-1	114.14	72.34	93.20	96.33
T_{12}- BA 20 mg.l-1	130.16	71.29	67.04	88.56
T_{13}- BA 30 mg.l-1	128.81	92.09	121.67	110.86
T_{14}- BA 40 mg.l-1	129.16	79.58	71.19	62.91
T_{15}- BA 50 mg.l-1	128.57	71.06	96.37	106.26
T_{16}- MH 100 mg.l-1	116.50	57.22	73.74	90.92
T_{17}- MH 150 mg.l-1	129.10	62.82	70.29	82.59
T_{18}-MH 200 mg.l-1	126.87	71.46	82.92	91.56
T_{19}-MH-250 mg.l-1	129.78	75.60	78.48	95.52
T_{20}-Control water spray	122.60	83.85	78.97	67.34
SEM ±	11.58	4.21	5.44	4.96
CD at 5%	NS	11.67	15.07	13.74

Table 7. Effect of different plant growth regulators on RGR in *Withania somnifera* at various growth stages

Treatment	30-60 DAS	60-90 DAS	90-12DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	0.033	0.006	0.006	0.005
T_2-IBA 100 mg.l-1	0.029	0.010	0.005	0.005
T_3 -IBA 150 mg.l-1	0.029	0.014	0.006	0.003
T_4-IBA 200 mg.l-1	0.033	0.006	0.007	0.004
T_5-IBA 250 mg.l-1	0.030	0.011	0.006	0.005
T_6-Ethrel 100 mg.l-1	0.032	0.009	0.005	0.002
T_7-Ethrel 150 mg.l-1	0.031	0.014	0.003	0.004
T_8- Ethrel 200 mg.l-1	0.032	0.009	0.005	0.004
T_9- Ethrel 250 mg.l-1	0.030	0.011	0.005	0.004
T_{10}- Ethrel 300 mg.l-1	0.032	0.014	0.002	0.003
T_{11}- BA 10 mg.l-1	0.030	0.015	0.003	0.002
T_{12}- BA 20 mg.l-1	0.033	0.013	0.003	0.002
T_{13}- BA 30 mg.l-1	0.029	0.018	0.002	0.002
T_{14}- BA 40 mg.l-1	0.030	0.019	0.002	0.001
T_{15}- BA 50 mg.l-1	0.032	0.013	0.004	0.004
T_{16}- MH 100 mg.l-1	0.029	0.020	0.002	0.002
T_{17}- MH 150 mg.l-1	0.028	0.013	0.004	0.001
T_{18}-MH 200 mg.l-1	0.030	0.012	0.003	0.002
T_{19}-MH-250 mg.l-1	0.032	0.013	-0.003	0.002
T_{20}-Control water spray	0.028	0.009	0.004	0.003
SEM ±	0.00134	0.00128	0.00094	0.00081
CD at 5%	NS	0.00354	0.00259	0.00224

Table 8. Effect of different plant growth regulators on CGR in Ashwagandha (*Withania somnifera*) *at* various growth stages

Treatment	30-60 DAS	60-90 DAS	90- 120 DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	4.70	8.01	8.70	7.60
T_2-IBA 100 mg.l-1	6.86	8.30	9.40	6.40
T_3 -IBA 150 mg.l-1	5.98	10.90	11.80	5.80
T_4-IBA 200 mg.l-1	4.00	7.89	8.20	7.40
T_5-IBA 250 mg.l-1	6.66	8.20	10.30	8.00
T_6-Ethrel 100 mg.l-1	8.12	7.50	6.10	5.90
T_7-Ethrel 150 mg.l-1	6.70	12.40	6.80	4.80
T_8- Ethrel 200 mg.l-1	7.94	7.30	7.80	6.70
T_9- Ethrel 250 mg.l-1	7.00	8.90	6.70	5.90
T_{10}- Ethrel 300 mg.l-1	7.30	13.20	4.90	3.40
T_{11}- BA 10 mg.l-1	6.63	13.60	4.50	4.00
T_{12}- BA 20 mg.l-1	8.20	12.50	5.20	3.20
T_{13}- BA 30 mg.l-1	6.61	19.00	4.10	4.20
T_{14}- BA 40 mg.l-1	6.91	21.30	5.00	3.20
T_{15}- BA 50 mg.l-1	7.74	12.60	7.80	5.60
T_{16}- MH 100 mg.l-1	6.22	21.80	4.20	4.20
T_{17}- MH 150 mg.l-1	5.21	9.40	4.10	2.00
T_{18}-MH 200 mg.l-1	6.64	10.20	3.90	3.00
T_{19}-MH-250 mg.l-1	7.74	12.10	5.70	-4.30
T_{20}-Control water spray	6.80	12.00	7.80	-5.60
SEM ±	0.59	1.23	1.33	0.84
CD at 5%	1.64	3.50	3.69	2.30

Table 9. Effect of different plant growth regulators on LWR in *Withania somnifera* at various growth stages

Treatment	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	0.0069	0.0072	0.0040	0.0021
T_2-IBA 100 mg.l-1	0.0072	0.0081	0.0045	0.0028
T_3 -IBA 150 mg.l-1	0.0087	0.0090	0.0043	0.0028
T_4-IBA 200 mg.l-1	0.0071	0.0086	0.0055	0.0026
T_5-IBA 250 mg.l-1	0.0083	0.0087	0.0048	0.0028
T_6-Ethrel 100 mg.l-1	0.0071	0.0078	0.0043	0.0023
T_7-Ethrel 150 mg.l-1	0.0080	0.0081	0.0036	0.0021
T_8- Ethrel 200 mg.l-1	0.0073	0.0081	0.0046	0.0022
T_9- Ethrel 250 mg.l-1	0.0072	0.0082	0.0044	0.0024
T_{10}- Ethrel 300 mg.l-1	0.0072	0.0071	0.0036	0.0019
T_{11}- BA 10 mg.l-1	0.0081	0.0084	0.0041	0.0029
T_{12}- BA 20 mg.l-1	0.0070	0.0072	0.0037	0.0025
T_{13}- BA 30 mg.l-1	0.0075	0.0073	0.0028	0.0019
T_{14}- BA 40 mg.l-1	0.0069	0.0069	0.0028	0.0022
T_{15}- BA 50 mg.l-1	0.0065	0.0065	0.0034	0.0019
T_{16}- MH 100 mg.l-1	0.0082	0.0086	0.0028	0.0016
T_{17}- MH 150 mg.l-1	0.0096	0.0106	0.0052	0.0032
T_{18}-MH 200 mg.l-1	0.0074	0.0082	0.0040	0.0024
T_{19}-MH-250 mg.l-1	0.0071	0.0075	0.0043	0.0026
T_{20}-Control water spray	0.0072	0.0067	0.0040	0.0028
SEM ±	0.0005	0.0005	0.0002	0.0001
CD at 5%	0.0014	0.0014	0.0007	0.0003

Table 10. Effect of different plant growth regulators on LAD in *Withania somnifera at* various growth stages

Treatment	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	37.04	69.66	57.06	46.04
T_2-IBA 100 mg.l-1	38.05	78.98	74.79	67.41
T_3 -IBA 150 mg.l-1	41.11	81.54	73.89	67.37
T_4-IBA 200 mg.l-1	38.07	81.36	72.81	53.78
T_5-IBA 250 mg.l-1	39.29	81.86	78.44	67.23
T_6-Ethrel 100 mg.l-1	39.41	82.44	70.16	50.04
T_7-Ethrel 150 mg.l-1	40.12	82.67	68.63	52.65
T_8- Ethrel 200 mg.l-1	40.89	89.27	74.16	51.35
T_9- Ethrel 250 mg.l-1	36.75	84.02	70.29	56.61
T_{10}- Ethrel 300 mg.l-1	35.08	81.68	71.24	46.44
T_{11}- BA 10 mg.l-1	41.27	87.21	84.74	72.27
T_{12}- BA 20 mg.l-1	40.36	85.37	78.03	62.96
T_{13}- BA 30 mg.l-1	38.17	79.92	71.06	54.99
T_{14}- BA 40 mg.l-1	35.78	79.34	76.50	71.78
T_{15}- BA 50 mg.l-1	34.56	77.49	71.01	53.28
T_{16}- MH 100 mg.l-1	39.74	90.45	75.65	50.85
T_{17}- MH 150 mg.l-1	41.20	84.74	77.09	57.78
T_{18}-MH 200 mg.l-1	37.73	79.20	67.68	50.63
T_{19}-MH-250 mg.l-1	39.41	84.83	73.26	49.23
T_{20}-Control water spray	40.55	82.08	78.89	64.85
SEM ±	0.73	1.53	1.88	1.99
CD at 5%	2.03	4.23	5.10	5.51

Table 11. Effect of different plant growth regulators on BMD in Ashwagandha (*Withania somnifera*) at various growth stages

Treatment	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS
T_1 –IBA 50 mg.l-1	4405.5	10125.0	15660.0	22995.0
T_2-IBA 100 mg.l-1	4023.0	10845.0	17460.0	24570.0
T_3 -IBA 150 mg.l-1	3519.0	11115.0	17910.0	25110.0
T_4-IBA 200 mg.l-1	4369.5	9720.0	14850.0	21465.0
T_5-IBA 250 mg.l-1	3843.0	10530.0	17820.0	26055.0
T_6-Ethrel 100 mg.l-1	4536.0	11565.0	17595.0	21510.0
T_7-Ethrel 150 mg.l-1	3825.0	12420.0	20160.0	25380.0
T_8- Ethrel 200 mg.l-1	4437.0	11295.0	17595.0	24120.0
T_9- Ethrel 250 mg.l-1	4050.0	11205.0	17865.0	23535.0
T_{10}- Ethrel 300 mg.l-1	4095.0	13320.0	20790.0	24525.0
T_{11}- BA 10 mg.l-1	3856.5	12960.0	21105.0	24930.0
T_{12}- BA 20 mg.l-1	4500.0	13815.0	21780.0	25560.0
T_{13}- BA 30 mg.l-1	3865.5	15390.0	25830.0	29565.0
T_{14}- BA 40 mg.l-1	4000.5	16695.0	28530.0	32220.0
T_{15}- BA 50 mg.l-1	4347.0	13500.0	21780.0	27900.0
T_{16}- MH 100 mg.l-1	3681.0	16290.0	27990.0	31770.0
T_{17}- MH 150 mg.l-1	3145.5	9720.0	15795.0	18540.0
T_{18}-MH 200 mg.l-1	3852.0	11430.0	17775.0	20880.0
T_{19}-MH-250 mg.l-1	4347.0	13275.0	16785.0	21915.0
T_{20}-Control water spray	4464.0	15480.0	19755.0	22860.0
SEM ±	278.69	656.47	914.69	756.69
CD at 5%	NS	1819	2523	2097

Table 12. Effect of different plant growth regulators on of plant height (cm) plant at various growth stages in *Withania somnifera*

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1 –IBA 50 mg.l-1	3.53	37.73	38.73	39.67	41.27
T_2-IBA 100 mg.l-1	3.40	31.60	34.00	37.60	38.07
T_3 -IBA 150 mg.l-1	3.80	27.87	31.40	36.13	37.80
T_4-IBA 200 mg.l-1	3.67	26.33	29480	30.80	32.00
T_5-IBA 250 mg.l-1	3.87	22.60	28.80	31.53	33.33
T_6-Ethrel 100 mg.l-1	4.00	22.20	33.27	34.27	36.20
T_7-Ethrel 150 mg.l-1	3.60	23.87	32.58	32.93	34.67
T_8- Ethrel 200 mg.l-1	3.67	23.60	32.50	35.00	35.87
T_9- Ethrel 250 mg.l-1	3.87	22.67	31.53	31.87	34.87
T_{10}- Ethrel 300 mg.l-1	4.07	23.27	29.53	33.80	33.93
T_{11}- BA 10 mg.l-1	3.78	20.47	31.73	34.80	35.27
T_{12}- BA 20 mg.l-1	2.97	24.33	29.80	34.67	35.47
T_{13}- BA 30 mg.l-1	3.53	26.40	33.07	34.20	35.27
T_{14}- BA 40 mg.l-1	3.27	25.00	32.87	34.30	37.20
T_{15}- BA 50 mg.l-1	3.93	22.93	33.33	34.27	35.87
T_{16}- MH 100 mg.l-1	3.47	21.40	32.47	32.73	35.80
T_{17}- MH 150 mg.l-1	3.47	23.60	32.00	31.27	35.70
T_{18}-MH 200 mg.l-1	3.33	25.93	30.00	30.80	33.20
T_{19}-MH-250 mg.l-1	3.37	19.00	28.00	30.20	31.40
T_{20}-Control water spray	3.87	32.07	34.00	36.37	37.87
SEM ±	0.32	1.49	1.69	1.13	1.04
CD at 5%	NS	4.10	4.70	3.11	2.90

Table 13. Effect of different plant growth regulators on number of nodes per plant at various growth stages in *Withania somnifera*

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1 –IBA 50 mg.l-1	4.47	9.67	11.40	12.80	17.27
T_2-IBA 100 mg.l-1	4.33	11.87	12.60	13.67	15.80
T_3 -IBA 150 mg.l-1	4.73	12.60	12.80	15.27	17.33
T_4-IBA 200 mg.l-1	4.33	9.47**	13.40	13.73	15.73
T_5-IBA 250 mg.l-1	4.80	13.00	12.40	13.80	19.00
T_6-Ethrel 100 mg.l-1	4.53	13.20	13.53	13.60	16.40
T_7-Ethrel 150 mg.l-1	4.07	11.60	11.93	13.60	17.47
T_8- Ethrel 200 mg.l-1	4.27	12.93	12.60	13.80	18.60
T_9- Ethrel 250 mg.l-1	4.27	11.20	12.47	13.87	16.40
T_{10}- Ethrel 300 mg.l-1	4.40	12.87	14.27	13.67	19.00
T_{11}- BA 10 mg.l-1	4.40	13.53	13.40	16.20	17.73
T_{12}- BA 20 mg.l-1	3.93	11.80	13.40	13.47	17.47
T_{13}- BA 30 mg.l-1	4.40	9.80	14.00	14.13	20.40
T_{14}- BA 40 mg.l-1	4.13	10.37	12.00	12.93	19.87
T_{15}- BA 50 mg.l-1	4.53	11.73	12.93	13.07	19.53
T_{16}- MH 100 mg.l-1	4.33	13.80	9.13	13.87	19.60
T_{17}- MH 150 mg.l-1	4.53	11.60	10.13	13.13	20.93
T_{18}-MH 200 mg.l-1	4.13	12.33	11.00	12.53	18.60
T_{19}-MH-250 mg.l-1	4.53	13.73	12.80	13.53	19.80
T_{20}-Control water spray	4.60	12.13	12.93	14.00	19.27
SEM ±	0.41	0.76	0.87	0.51	1.30
CD at 5%	NS	NS	NS	NS	NS

Table 14. Effect of different plant growth regulators on number of branches per plant at various growth stages in *Withania somnifera*

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1 –IBA 50 mg.l-1	0.00	4.00	3.53	3.73	3.20
T_2-IBA 100 mg.l-1	0.00	3.73	3.87	3.07	3.13
T_3 -IBA 150 mg.l-1	0.00	3.33	4.07	2.87	2.93
T_4-IBA 200 mg.l-1	0.00	4.07	3.27	3.00	3.40
T_5-IBA 250 mg.l-1	0.00	3.40	3.67	2.73	3.40
T_6-Ethrel 100 mg.l-1	0.00	2.93	4.13	3.40	3.07
T_7-Ethrel 150 mg.l-1	0.00	3.57	4.13	3.20	3.00
T_8- Ethrel 200 mg.l-1	0.00	3.87	4.20	3.33	3.40
T_9- Ethrel 250 mg.l-1	0.00	3.93	3.73	3.20	3.47
T_{10}- Ethrel 300 mg.l-1	0.00	3.20	3.60	2.80	3.20
T_{11}- BA 10 mg.l-1	0.00	3.53	3.60	4.20	3.73
T_{12}- BA 20 mg.l-1	0.00	3.13	3.93	3.73	3.60
T_{13}- BA 30 mg.l-1	0.00	3.07	3.67	3.93	3.40
T_{14}- BA 40 mg.l-1	0.00	3.73	3.80	3.73	3.20
T_{15}- BA 50 mg.l-1	0.00	3.87	4.13	3.27	2.40
T_{16}- MH 100 mg.l-1	0.00	3.07	3.73	3.27	3.47
T_{17}- MH 150 mg.l-1	0.00	3.40	3.07	2.53	3.07
T_{18}-MH 200 mg.l-1	0.00	3.47	3.67	3.13	2.80
T_{19}-MH-250 mg.l-1	0.00	3.13	3.53	3.47	2.47
T_{20}-Control water spray	0.00	2.67	3.93	3.67	3.07
SEM ±	0.00	0.46	0.41	0.42	0.39
CD at 5%	0.00	NS	NS	NS	NS

Table 15. Effect of different plant growth regulators on number of leaves per plant at various growth stages in Withania *somnifera*

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1 –IBA 50 mg.l-1	7.20	42.20	51.20	54.00	36.60
T_2-IBA 100 mg.l-1	7.27	38.53	61.00	62.20	32.40
T_3 -IBA 150 mg.l-1	7.27	39.60	61.67	63.33	33.20
T_4-IBA 200 mg.l-1	7.67	38.87	52.20	55.33	28.20
T_5-IBA 250 mg.l-1	7.67	46.53	52.13	55.20	26.40
T_6-Ethrel 100 mg.l-1	7.80	43.93	59.47	61.00	29.40
T_7-Ethrel 150 mg.l-1	7.27	40.73	48.80	51.39	28.53
T_8- Ethrel 200 mg.l-1	7.60	42.73	60.93	62.00	33.00
T_9- Ethrel 250 mg.l-1	7.60	38.93	61.80	63.00	28.87
T_{10}- Ethrel 300 mg.l-1	7.60	40.53	55.93	58.00	28.47
T_{11}- BA 10 mg.l-1	7.33	44.47	61.07	63.00	29.60
T_{12}- BA 20 mg.l-1	6.80	43.40	62.00	65.00	36.87
T_{13}- BA 30 mg.l-1	6.87	41.13	61.73	62.00	34.37
T_{14}- BA 40 mg.l-1	7.20	40.73	59.27	60.20	31.87
T_{15}- BA 50 mg.l-1	7.33	38.07	60.50	63.00	31.27
T_{16}- MH 100 mg.l-1	7.33	43.00	60.63	62.00	30.53
T_{17}- MH 150 mg.l-1	6.93	41.20	55.93	58.33	29.20
T_{18}-MH 200 mg.l-1	6.73	40.33	58.93	59.00	32.60
T_{19}-MH-250 mg.l-1	6.47	42.93	56.93	58.33	28.53
T_{20}-Control water spray	7.33	44.73	47.33	49.33	35.80
SEM ±	0.34	2.05	3.46	4.86	2.29
CD at 5%	NS	NS	NS	NS	NS

Table 16. Effect of different plant growth regulators on root length (cm) per plant at various growth stages in *Withania somnifera*

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1 –IBA 50 mg.l-1	3.53	16.80	16.47	21.00	21.40
T_2-IBA 100 mg.l-1	3.87	17.93	19.47	23.00	26.63
T_3 -IBA 150 mg.l-1	3.60	16.73	20.87	25.33	26.40
T_4-IBA 200 mg.l-1	3.27	14.53	18.07	20.10	20.90
T_5-IBA 250 mg.l-1	3.50	14.00	17.33	20.13	20.93
T_6-Ethrel 100 mg.l-1	3.87	16.07	18.00	20.93	22.40
T_7-Ethrel 150 mg.l-1	3.40	15.87	18.40	18.47	23.87
T_8- Ethrel 200 mg.l-1	3.60	15.73	19.40	19.87	21.40
T_9- Ethrel 250 mg.l-1	4.00	13.87	16.67	16.47	18.87
T_{10}- Ethrel 300 mg.l-1	4.27	16.07	17.07	18.07	19.00
T_{11}- BA 10 mg.l-1	3.47	12.87	17.13	16.93	19.40
T_{12}- BA 20 mg.l-1	3.93	12.13	16.33	18.93	18.20
T_{13}- BA 30 mg.l-1	3.40	11.27	17.53	17.73	20.13
T_{14}- BA 40 mg.l-1	3.40	15.93	16.40	21.40	17.87
T_{15}- BA 50 mg.l-1	3.33	15.27	17.33	19.13	19.13
T_{16}- MH 100 mg.l-1	3.47	14.93	17.73	21.47	21.13
T_{17}- MH 150 mg.l-1	3.60	15.33	16.60	17.07	18.93
T_{18}-MH 200 mg.l-1	3.33	15.33	16.20	17.20	19.73
T_{19}-MH-250 mg.l-1	2.93	14.40	17.67	19.67	18.93
T_{20}-Control water spray	3.73	14.93	19.47	19.87	20.90
SEM ±	0.27	0.61	0.62	1.46	1.63
CD at 5%	NS	1.68	1.72	4.01	4.49

Table 16. Bio mass partitioning (q/ha) and yield (q/ha) at maturity of Ashwagandha (*Withania somnifera*)

Treatment	Leaves	Stem	Root	Fruit	Seed	Total biomass	HI (%)taking roots as economic yield
T_1 –IBA 50 mg.l-1	5.46	9.70	8.81	4.24	1.08	28.21	31.24
T_2-IBA 100 mg.l-1	6.43	9.83	11.05	4.89	1.14	32.2	34.32
T_3 -IBA 150 mg.l-1	3.70	7.86	8.99	4.17	1.64	24.72	36.37
T_4-IBA 200 mg.l-1	3.60	7.76	9.87	3.98	1.14	25.21	39.16
T_5-IBA 250 mg.l-1	3.13	8.66	10.90	4.86	1.34	27.55	39.57
T_6-Ethrel 100 mg.l-1	3.30	9.06	10.05	5.72	1.26	28.13	35.73
T_7-Ethrel 150 mg.l-1	3.66	8.60	9.36	5.02	1.29	26.64	35.14
T_8- Ethrel 200 mg.l-1	3.36	7.96	7.78	3.97	0.87	23.07	33.73
T_9- Ethrel 250 mg.l-1	4.23	9.23	8.57	5.59	1.68	27.62	31.03
T_{10}- Ethrel 300 mg.l-1	4.53	7.93	8.04	5.37	1.59	25.87	31.08
T_{11}- BA 10 mg.l-1	4.20	9.46	8.02	4.64	1.26	26.32	30.48
T_{12}- BA 20 mg.l-1	4.03	8.20	8.28	4.80	1.14	25.31	32.72
T_{13}- BA 30 mg.l-1	4.56	7.40	6.96	5.82	1.36	24.74	28.14
T_{14}- BA 40 mg.l-1	5.50	9.76	11.45	5.97	1.42	32.68	35.04
T_{15}- BA 50 mg.l-1	5.26	8.80	7.70	5.43	1.27	27.19	28.32
T_{16}- MH 100 mg.l-1	4.76	6.66	9.73	4.30	1.01	25.45	38.24
T_{17}- MH 150 mg.l-1	3.83	6.80	9.81	3.87	0.94	24.31	40.36
T_{18}-MH 200 mg.l-1	3.20	8.06	9.31	4.29	0.97	24.86	37.45
T_{19}-MH-250 mg.l-1	3.50	6.56	9.62	3.51	0.89	23.19	41.49
T_{20}-Control water spray	3.96	8.76	8.33	3.38	0.67	24.43	34.09
SEM ±	0.23	0.54	0.42	0.37	0.064	0.60	0.64
CD at 5%	0.64	1.50	1.15	0.72	0.17	1.66	1.78

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