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Effect of drip fertigation on growth, seed and root yield of ashwagandha [Withania somnifera (L.) Dunal]

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Abstract:	An experiment was conducted during 2005-06 and 2006-07 winter seasons to study the effect of drip irrigation regimes and fertility levels on physiological parameters, growth and yield of ashwagandha (Withania somnifera L. Dunal). The treatments consisted of three irrigation regimes (I1- drip irrigation at 100% pan evaporation (PE), I2 at 80% PE and I3 at 60% PE) combined with three fertility levels (F1 -100%, F2 - 75% and F3 - 50% recommended dose of NPK) with an extra (control) treatment having surface irrigation and soil application of fertilizers. The cultivation of ashwagandha with application of drip irrigation at 80% of pan evaporation along with application of full dose of fertilizers (100% RD through fertigation) resulted in significant improvement in growth, physiological parameters (CGR, RGR, Chlorophyll content, NAR and LAI), and root and seed yields.
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Effect of drip fertigation on growth, seed and root yield of ashwagandha [*Withania somnifera* (L.) Dunal]

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ABSTRACT

An experiment was conducted during 2005-06 and 2006-07 *winter* seasons to study the effect of drip irrigation regimes and fertility levels on physiological parameters, growth and yield of ashwagandha (*Withania somnifera* **L.** Dunal). The treatments consisted of three irrigation regimes (I_1- drip irrigation at 100% pan evaporation (PE), I_2 at 80% PE and I_3 at 60% PE) combined with three fertility levels (F_1 -100%, F_2 – 75% and F_3 - 50% recommended dose of NPK) with an extra (control) treatment having surface irrigation and soil application of fertilizers. The cultivation of ashwagandha with application of drip irrigation at 80% of pan evaporation along with application of full dose of fertilizers (100% RD through fertigation) resulted in significant improvement in growth, physiological parameters (CGR, RGR, Chlorophyll content, NAR and LAI), and root and seed yields.

Key words: Ashwagandha; medicinal crop; method of irrigation and physiological parameters.

Withania somnifera **L.** Dunal commonly known as Ashwagandha is one of the important medicinal crops in Ayurvedic medicine system and an indigenous medicine for over 3000 years in India (Shrivastava and Sahu, 2013) which is having high economic value. In India *Withania somnifera* is cultivated in around 10,780 ha with an annual root production of 8429 tonnes (Shrivastava and Sahu, 2013). The cultivation of this plant during post-rainy season would be of great significance as many of the farmers either keep the land fallow or cultivate *winter* pulses with low yield and economic returns. Irrigation and fertilization are the key inputs that affect growth, yield parameters and quality of ashwagandha. The factor productivity is declining which needs scientific management. Among the irrigation methods, drip fertigation system (combined use of water and nutrient) is considered to be the most

efficient in improving yield, water use efficiency and saving of water by affecting the physiological parameters, studies on the effects of fertigation on growth and yield of ashwagandha under Indian conditions are limited. Hence, keeping this in view, the present investigation was carried out to study the effect of drip-fertigation on physiological parameters, growth and yield of *Withania somnifera*.

The field experiments were conducted at the Directorate of Water Management, Bhubaneswar during *Winter* (October-March) seasons of 2005-06 and 2006-07 to study the effect of drip irrigation regimes and fertigation levels on growth and physiology of Ashwagandha (*Withania somnifera*) in the rice - fallow system. The experimental site was located at 20^{o} 30' N latitude and 87^{o} 48' E longitude at an elevation of 45 m above the mean sea level having a warm and moist climate with hot and humid summer and mild winter and with a mean annual rainfall of 1439 mm. The total evaporation from open pan was 572 mm in 2005-06 and 541 mm in 2006-07. The soil of the experimental field was sandy clay (*Aeric Haplaquept*), acidic in nature (pH 5.7), low in organic carbon (0.46%) and nitrogen (159 kg ha^{-1}, medium in available phosphorus (21 kg ha^{-1}) and potassium (183 kg ha^{-1}). The experiment was laid out in a factorial randomized block design with three replications. Three levels of irrigation [(I_1- Drip irrigation at 100% Pan Evaporation (100% PE); I_2- Drip irrigation at 80% Pan Evaporation (80% PE); I_3- Drip irrigation at 60% Pan Evaporation (60% PE)] were combined with three levels of fertilizers [F1- 100% NPK of the recommended dose (RD); F2-75% NPK of RD; F3-50% NPK of RD]. An extra control treatment (farmers' practice) was included with surface furrow irrigation and soil application of fertilizers. In control treatment, surface irrigation of 6 cm depth was applied in furrows at 60 mm CPE with application of 100% RD of fertilizers. The ashwagandha variety '*Jawahar Ashwagandha-20*' was transplanted at a spacing of 30 cm X 10 cm and a fertilizer dose of 30-30-20 kg N-P_2O_5-K_2O ha^{-1} was applied. Fifty days old seedlings were used for transplanting. The fertilizers used for supplying NPK were urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Fertigations were given in equal splits at fortnight interval from 15 days after planting (DAP) up to 30 days before harvest. Required amounts of urea and potash were dissolved in water and fed to the drip using ventury system. Different irrigation levels were imposed on the basis of pan evaporation through meteorological approach (Jenson et al., 1961).

Height of the plants was recorded from the ground surface up to the top most growing point. The leaf area index was calculated by using the formula suggested by Watson, (1952).

Leaf area index = (Total leaf area per plant in $m^2 \times$ number of plants m^{-2}) / (Land area in m^2).

Chlorophyll content in the leaves of Ashwagandha was determined spectrophotomerically (Model: Chemito, 2600) as suggested by Duxbury and Yentsch, (1956). The crop growth rate (CGR) and relative growth rate (RGR) were calculated by using the formulae suggested by Redford, (1967) and were expressed in g m^{-2} day^{-1} and g g^{-1} day^{-1}, respectively. CGR = $(W_2 - W) / (t_2 - t_1)$; where, W_2 and W_1 are the dry matter production (g m^{-2}) at time t_2 and t_1 in days; RGR = $(Log_e W_2 - Log_e W / t_2 - t_1)$; where, W_2 and W_1 are the dry matter production (g m^{-2}) at time t_2 and t_1 in days. The net assimilation rate (NAR) was calculated by the formula suggested by Hunt, 1990 and was expressed in g dry matter m^{-2} leaf area d^{-1}. NAR = $\{W_2 - W_1 / (t_2 - t_1)\}$ x $\{(InA_2 - InA_1) / (A_2 - A_1)\}$; where, W_1 and W_2 are the total dry weight (g m^{-2}) at time t_1 and t_2 respectively, A_1 and A_2 are leaf area indices (LAI) at time t_1 and t_2 respectively.

Roots were cut into 7 to 10 cm long pieces, shade dried to maintain a moisture content of 12%. The fruits were plucked separately and dried in the sun and expressed in kg/ha. The pooled data for the two years were analysed using the F-test according to Gomez and Gomez (1984). Least significant difference (LSD) values at p = 0.05 were used to determine the significance of differences between treatment means.

Drip irrigation produced taller plants (28.4% higher) than surface irrigation at harvesting stages. The level of irrigation significantly affected the plant height in all the stages (Table 1). Irrigation at 80% PE increased the height from 3.3% to 15.5% at harvesting stage as compared to that of 100% PE and 60% PE. Variation in fertility also influenced the plant height (Table 1). Application of 100% RD increased the height by 3.6% and 6.5% as compared to 75% and 50% RD respectively. The interaction effect was found significant. Application of irrigation at 80% PE with 100% RD produced the taller plants (58 cm). Significant effect on number of branches was noticed due to method of irrigation in all the stages except at 135 DAS (Table 1). Irrigation levels significantly affected the branch number during all the stages. Irrigation at 80% PE increased the branch number by 7.0% and 21% in as compared to 100% to 60% PE. Fertilizing the crop with 100% RD increased the number of branches per plant by 15.6% to 24.8% compared to 75% and 50% recommended dose.

Drip irrigation increased leaf area index by 7.5% at 135 days which was peak growth period after planting (Table 2). Application of irrigation at 80% PE increased the LAI marginally (0.5% to 2.9%) as compared to that of 100% PE and 60% PE at 135 DAP (Table 2). Application of 100% RD of fertilizers showed the highest value of the index (1.6) at 165 DAP followed by 75% RD and 50% RD. The dry matter production in ashwagandha was influenced significantly by method and level of irrigation and fertilizers (Table 2). Drip irrigation increased the dry matter production by 38% at harvest stage compared to surface irrigation and fertilizer application. Irrigation at 80% PE had maximum dry matter production followed by 100% PE and 60% PE. Application of full dose of fertilizer (100% RD) produced maximum quantity of dry matter (926.56 g m^{-2}) as compared to other fertility levels (F_2 and F_3).

The crop growth rate (CGR) was significantly influenced by various methods and levels of irrigation and fertility (Table 3). A progressive increase in CGR was observed up to 135 DAP after which it decreased. It was approximately doubled during 75-105 DAP and 135-165 DAP by drip irrigation as compared with surface method (control). Among the irrigation level, the highest crop growth rate was recorded with irrigation at 80%. Among the fertilizer levels, the highest growth rate was observed with 100% RD of fertilizers, which decreased with reduction in fertilizer dose. The relative growth rate (RGR) was maximum during 105-135 DAP and decreased till harvest (Table 3). It was higher in case of drip irrigation method than the surface irrigation. At 105-135 DAP and 165 DAP to harvest stage, it was higher in case of surface irrigation than drip. Irrigation at frequent intervals affected the RGR and it was maximum with 80% PE (I_2). The highest relative growth rate (0.0094 g g^{-1} day^{-1}) was achieved through irrigation at 80% PE and lowest with 60% PE (0.0072 g g^{-1} day^{-1}) at 105-135 DAP. An increase in fertilizer dose increased the RGR at most of the stages. The growth rate was maximum (0.0081 g g^{-1} day^{-1}) with 100% RD and it decreased with reduction in fertilizer dose at 105-135 DAP. Application of drip irrigation increased the chlorophyll (0.85 mg g^{-1}) compared to surface flow irrigation (83 mg g^{-1}) (Table 4). Application of irrigation at 80% PE recorded highest chlorophyll content (0.89 mg g^{-1}) followed by 100% PE (0.86 mg g^{-1}). Reduction in irrigation level after 80% PE decreased the chlorophyll content. Application of 100% RD of fertilizers increased the chlorophyll content. Lowest chlorophyll content was recorded with 50% RD (0.83 mg g^{-1}). The interaction effect

of irrigation and fertility was not significant. Drip irrigation induced higher rate of assimilation up to 165 DAP as compared to furrow irrigation. Irrigation at 80% PE had higher rate of assimilation than the other two levels at all the growth stages. Application of full dose of fertilizer (100% RD) had maximum net assimilation rate at most of the growth stages, which decreased slowly up to 50% RD. The interaction effect was not significant at most of the stages except 30-60 DAP in both the seasons.

Root yield was significantly influenced by the irrigation method, level of irrigation and fertility (Table 4). Drip irrigation recorded maximum root yield (705 kg ha^{-1}), which was 8.8% more than that of surface irrigation method (648 kg ha^{-1}). Maximum root yield (795 kg ha^{-1}) was obtained with irrigation at 80% PE followed by 100% PE (727 kg ha^{-1}). Application of full dose of fertilizer (100% RD) produced maximum root yield (745 kg ha^{-1}), which was 4.9% and 12.9% more than that of 75 % RD of fertilizers (710 kg ha^{-1}) and 50% RD of fertilizers (660 kg ha^{-1}). Drip irrigation produced higher quantity of seed (73 kg ha^{-1}) than surface irrigation. Application of irrigation at 80% PE produced maximum seed yield (78 kg ha^{-1}) followed by 100% PE (76 kg ha^{-1}) and 60% PE (65 kg ha^{-1}). Maximum seed yield (75 kg ha^{-1}) obtained through application of 100% RD, which was 1.3% to 7.2% more than 75% RD (74 kg ha^{-1}) and 50% RD (69 kg ha^{-1}).

The substantial increase in the values of various growth, physiological parameters and yield of ashwagandha under drip irrigation was mainly due to maintenance of soil moisture at optimum range. Greater availability of soil water in case of drip irrigation might have increased the availability of nutrients and its uptake. The leaf area was higher under drip system compared to surface irrigation due to higher leaf production and delayed senescence. Application of irrigation at 100% PE caused excess moisture conditions whereas at 60% PE, there was shortage of moisture. Hence, the growth parameters were better under 80% PE than the other levels. The improvement in the yields under drip irrigation might be due to the maintenance of higher available soil moisture nearer to field capacity in the root zone particularly at shallow depth helping in increasing photosynthesis and more biomass production contributing to the yield. High fluctuation in soil moisture at root zone resulted in poor yield under surface irrigation. Influence of drip irrigation in increasing the yield attributes compared to surface irrigation has been reported in tapioca (Yuan *et al*., 2003). Fertigation through drip system resulted in taller plants, more leaf area, number of branches

and dry root yield due to increased nutrient availability at root zone. Cassel *et al*. (2001) reported positive influence of fertigation on growth parameters as compared to soil application of fertilizer to sugar beet. Application of 100% RD of fertilizers enhanced plant height, number of branches per plant, dry matter accumulation and chlorophyll content of ashwagandha due to better availability of nutrients in a balanced manner (Pakkiyanthan *et al.,* 2004). Precision in application of fertilizers in right quantity at right time to match the crop demand enhanced the biochemical activities, which consequently led to better growth. Continuous availability of nutrients due to favourable moisture regime might have enhanced source capacity and sink strength, which in turn influenced the seed and root yields.

It is concluded that ashwagandha should be irrigated through drip irrigation at 80% of pan evaporation with application of full recommended dose of fertilizer (100% RD) to enhance its growth, physiological parameters and to achieve maximum root and seed yields.

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Tables Revised
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Table 1 Effect of irrigation and fertilizer application on plant height and number of branches per plant (Pooled data of two years)

Treatment	Height (cm)					Number of branches per plant				
	Days after planting					Days after planting				
	75	105	135	165	Harvest	75	105	135	165	Harvest
Method of irrigation										
Control	24.4	27.7	32.8	37.5	39.3	5.3	6.0	8.2	8.6	10.4
DF	32.0	35.7	38.0	45.2	50.5	6.4	6.5	8.9	10.3	11.1
SE (m)±	0.34	0.39	0.45	0.007	0.02	0.005	0.016	0.299	0.079	0.079
LSD (0.05)	0.72	0.82	0.94	0.014	0.05	0.012	0.034	NS	0.166	0.166
Irrigation (I)										
I_1 = 100% PE	31.6	35.8	37.6	45.4	51.8	6.4	6.6	9.3	10.7	11.3
I_2 = 80% PE	33.8	37.4	40.3	46.2	53.5	6.6	6.8	9.7	11.1	12.1
I_3 = 60% PE	30.8	34.1	36.4	43.9	46.3	6.1	6.3	8.0	9.1	10.0
SE (m)±	0.59	0.68	0.78	0.01	0.04	0.009	0.028	0.518	0.137	0.137
LSD (0.05)	1.25	1.43	1.63	0.02	0.08	0.020	0.059	1.089	0.289	0.288
Fertilizer application (F)										
F_1 = 100% RD	34.7	37.9	40.5	45.9	52.2	7.7	7.9	10.2	11.7	12.5
F_2 = 75% RD	32.0	35.4	37.9	45.1	50.4	6.3	6.5	8.5	10.2	10.9
F_3 = 50% RD	29.5	33.9	35.9	44.5	49.0	5.2	5.4	8.1	9.0	9.1
SE (m)±	0.59	0.68	0.78	0.01	0.04	0.009	0.028	0.518	0.137	0.137
LSD (0.05)	1.25	1.43	1.63	0.02	0.08	0.020	0.059	1.089	0.289	0.288
Interaction (I x F)										
SE (m)±	1.03	1.18	1.35	0.02	0.07	0.017	0.049	0.898	0.238	0.237
LSD (0.05)	NS	NS	NS	0.04	0.15	0.036	0.103	1.887	0.500	0.498

NS=Not significant

Table 2 Effect of irrigation and fertilizer application on leaf area index and dry matter accumulation (Pooled data of two years)

Treatment	Leaf Area Index					Dry matter accumulation (g m^{-2})				
	Days after planting					Days after planting				
	75	105	135	165	Harvest	75	105	135	165	Harvest
Method of irrigation										
Control	0.544	0.678	1.314	1.228	1.095	368.95	396.62	520.61	560.60	611.76
DF	0.560	0.747	0.353	1.528	1.309	490.78	558.94	710.42	791.98	846.65
SE (m)±	0.0002	0.006	0.007	0.0086	0.011	0.07	0.07	0.08	0.27	0.14
LSD (0.05)	0.0004	0.020	0.021	0.0181	0.040	0.16	0.14	0.17	0.57	0.31
Irrigation (I)										
I_1 = 100% PE	0.564	0.651	1.453	1.500	1.320	510.55	580.60	721.20	806.47	855.89
I_2 = 80% PE	0.599	0.797	1.428	1.600	1.413	531.92	621.58	822.35	926.63	1001.2
I_3 = 60% PE	0.519	0.680	1.394	1.486	1.194	429.89	474.28	587.75	642.86	682.80
SE (m)±	0.0003	0.012	0.012	0.0149	0.006	0.13	0.12	0.14	0.47	0.25
LSD (0.05)	0.0007	0.035	0.036	0.0313	0.020	0.28	0.25	0.29	0.98	0.54
Fertilizer application (F)										
F_1 = 100% RD	0.585	0.911	1.423	1.579	1.329	519.00	594.60	758.66	862.31	926.56
F_2 = 75% RD	0.550	0.763	1.411	1.543	1.320	492.48	561.60	710.15	782.90	837.55
F_3 = 50% RD	0.544	0.734	1.403	1.461	1.278	461.12	520.62	662.47	730.77	775.86
SE (m)±	0.0003	0.012	0.012	0.0149	0.006	0.13	0.12	0.14	0.47	0.25
LSD (0.05)	0.0007	0.035	0.036	0.0313	0.020	0.28	0.25	0.29	0.98	0.54
Interaction (I x F)										
SE (m)±	0.0006	0.02	0.021	0.0258	0.020	0.23	0.21	0.24	0.81	0.44
LSD (0.05)	0.0013	NS	NS	0.0543	0.053	NS	NS	NS	NS	NS

NS=Not significant

Table 3 Effect of irrigation and fertilizer application on CGR & RGR (Pooled data of two years)

Treatment	CGR (g m^{-2} day^{-1})				RGR (g g^{-1} day^{-1})			
	Days after planting				Days after planting			
	75-105	105-135	135-165	165-H	75-105	105-135	135-165	165-H
Method of irrigation								
Control	0.55	4.12	1.32	1.70	0.0024	0.0090	0.0026	0.0029
DF	2.26	5.04	5.34	1.82	0.0044	0.0080	0.0037	0.0023
SE(m)±	0.13	0.11	0.24	0.26	0.0003	0.0003	0.0002	0.0002
LSD (0.05)	0.40	0.32	0.74	NS	0.0009	0.0009	0.0006	0.0005
Irrigation (I)								
I_1 = 100 % PE	2.33	4.68	2.84	1.64	0.0043	0.0072	0.0038	0.0020
I_2 = 80 % PE	3.00	6.68	3.47	2.44	0.0052	0.0094	0.0040	0.0026
I_3 = 60 % PE	1.48	2.84	1.83	1.33	0.0033	0.0072	0.0030	0.0020
SE (m)±	0.23	0.19	0.36	0.46	0.0005	0.0004	0.0030	0.0005
LSD (0.05)	0.68	0.54	1.08	NS	0.0016	0.0013	0.0091	0.0014
Fertilizer application (F)								
F_1 = 100 % RD	2.52	5.46	3.45	2.14	0.0046	0.0081	0.0043	0.0024
F_2 = 75 % RD	2.30	4.94	2.42	1.82	0.0044	0.0078	0.0033	0.0023
F_3 = 50 % RD	1.98	4.73	2.27	1.50	0.0041	0.0080	0.0033	0.0023
SE (m)±	0.23	0.19	0.36	0.46	0.0005	0.0004	0.0030	0.0005
LSD (0.05)	0.68	0.54	1.08	NS	0.0016	0.0013	0.0091	0.0014
Interaction (I x F)								
SE (m)±	0.40	0.34	0.70	0.77	0.0010	0.0006	0.0005	0.0007
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS=Not significant, H=At harvest

Table 4 Effect of irrigation and fertilizer application on plant net assimilation rate, chlorophyll content, root yield and seed yield (Pooled data of two years)

Treatment	NAR (g $m^{-2}day^{-1}$) Days after planting				Chlorophyll Content (mg/ gram of fresh wt.)	Root Yield (kg ha^{-1})	Seed Yield (kg ha^{-1})
	75-105	105-135	135-165	165-H			
Method of irrigation							
Control	1.504	4.268	1.055	1.469	0.83	648	67
DF	3.504	4.818	1.855	1.287	0.85	705	73
SE(m)±	0.0014	0.0007	0.0009	0.0001	0.0009	3.34	0.26
LSD (0.05)	0.0031	0.0023	0.0020	0.0003	0.0020	9.93	0.79
Irrigation (I)							
I_1 = 100 % PE	3.531	4.391	1.956	1.170	0.86	727	76
I_2 = 80 % PE	4.360	6.178	2.302	1.652	0.89	795	78
I_3 = 60 % PE	2.477	3.787	1.281	0.997	0.81	593	65
SE (m)±	0.0025	0.0003	0.0017	0.0003	0.0017	5.79	0.46
LSD (0.05)	0.0054	0.0006	0.0036	0.0006	0.0036	17.19	1.37
Fertilizer application (F)							
F_1 = 100 % RD	3.489	4.741	2.310	1.491	0.88	745	75
F_2 = 75 % RD	3.540	4.685	1.649	1.276	0.86	710	74
F_3 = 50 % RD	3.130	4.566	1.593	1.098	0.83	660	69
SE (m)±	0.0025	0.0003	0.0017	0.0003	0.0017	5.79	0.46
LSD (0.05)	0.0054	0.0006	00036	0.0006	0.0036	17.19	1.37
Interaction (I x F)							
SE (m)±	0.0044	0.0009	0.0029	0.0005	0.0029	10.02	0.80
LSD (0.05)	0.0093	0.0029	0.0062	0.0011	0.0062	29.78	2.38

NS=Not significant, H=At harvest