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Dynamics of growth parameter and yield of kalmegh (*Andrographis paniculata*) under different weed control technique

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Abstract
Medicinal plants play a significant role in the life of people and are present in innumerable forms. Medicinal and Aromatic plants contribute significantly to our economy and health security of the country. Kalmegh is an important medicinal plant that has been effectively used in traditional Asian medicines. A field experiment was conducted during *kharif* season of 2015 at G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). Result reviled that maximum leaf area index, crop growth rate and relative growth rate were recorded in weed free treatment followed by T_8 (Three hand weeding) treatment at all stages of crop growth. The highest dry and fresh herbage yield was also recorded in weed free treatment followed by T_8 (Three hand weeding) treatment.

Keywords: Medicinal, Kalmegh, Harbage, LAI, CGR, RGR

1. Introduction
Medicinal plant is an integral part of human life to combat the sufferings from the dawn of civilization (Choudhary *et al*., 2010) [3]. It is estimated that more than 80,000 of total plant species have been identified and used as medicinal plants around the world (Joy *et al*., 1989). It is estimated that about 75–80% of people of developing countries and about 25% of people of developed countries depend either directly or indirectly on medicinal plants for the first line of treatment (Burkill *et al*., 1966) [2]. *Andrographis paniculata* is an important medicinal plant and widely used around the world. It belongs to the family Acanthaceae. *Andrographis paniculata* is used as a traditional herbal medicine in Bangladesh, China, Hong Kong, India, Pakistan, Philippines, Malaysia, Indonesia, and Thailand and is ethnobotanically used for the treatment of snake bite, bug bite, diabetes, dysentery, fever and malaria. The genus *Andrographis* consists of 40 species and about 19 species are reported to be available in India, out of which *Andrographis paniculata* and *Andrographis alata* have medicinal properties. In India, kalmegh is cultivated as rainy season crop. The climatic requirement of the plant is hot and humid condition with ample sunshine. Kalmegh can be cultivated in wide range of soil from loam to lateritic soil with moderate fertility.
All plant parts of kalmegh contain andrographolide but the leaves of kalmegh contain the highest amount of andrographolide. Kalmegh is a short duration crop and grown for medicinal purpose in *kharif* season and thus weed infestation is very high in this crop. Weeds deteriorate the quality and quantity of kalmegh, so if we manage the weed properly then we can increase leaf area index, crop growth rate, relative growth rate and herbage yield of plant. Hand weeding is best way of weed control if availability of labour Mirjha *et al.* (2013) [7].

2. Materials and method
2.1 Experimental site
The experiment was conducted at the Medicinal Plants Research and Development Centre, GB Pant University of Agriculture and Technology, U.S. Nagar (Uttarakhand) during the *kharif* season. The research centre lies in the *tarai* belt, 30 km southern end of foothills of Shivalik range of Himalaya at 29^0 latitude 79.5^0 E longitude and at an altitude of 243.83 m above mean sea level. *Tarai* belt is characterized by a sub-tropical and sub humid climate in which summer is hot and dry and winter is severe cold. Winter season falls between October-February, then summer season continues till the end of June. During summer, maximum temperature exceeds 40 ^{0}C while in winter, the minimum temperature occasionally touches 2 ^{0}C. Monsoon sets in the second or third week of June and continues up to the end of September.

Some rain is also received during winter months. The average rainfall of Pantnagar is 1420 mm and most of rains are received from South-West monsoon from June to September. The soil of the experimental area was silty clay loam in texture being low in available nitrogen (215.76 kg ha^{-1}), high in available phosphorus (29.38 kg ha^{-1}), medium in available potassium (231 kg ha^{-1}) and high organic carbon (0.88%) contents with near neutral in reaction (pH 7.3).

2.2 Experimental design and details of treatments

The crop was transplanted on July 15, 2013 as per the randomized complete block design with three replications. The crop was transplanted in row 40 cm apart and 30 cm within rows. Well rooted plants of *A. paniculata* cv. 'CIM-Megha' of uniform size and 45 days stage were transplanted in the experimental field followed by a light irrigation. The experiment, comprising of ten treatments

Table 1: Treatment details of the experiment

S. No	Treatment	Treatment details
1.	T_1	Pendimethalin PE @ 1 kg a.i. ha^{-1} followed by mechanical weeding by hand hoe at 30-35 DAT
2.	T_2	Quizalofop ethyl PoE at 3-5 leaf stage of weeds @ 50 g a.i. ha^{-1} followed by mechanical weeding by hand hoe at 30-35 DAT
3.	T_3	Pendimethalin PE @ 1 kg a.i. ha^{-1} + Quizalofop ethyl PoE at 3-5 leaf stage of weeds @ 50 g a.i. ha^{-1}
4.	T_4	Pendimethalin PE @ 1 kg a.i. ha^{-1} + Quizalofop ethyl PoE at 3-5 leaf stage of weeds @ 50 g a.i. ha^{-1} followed by mechanical weeding by hand hoe at 30-35 DAT
5.	T_5	Pendimethalin PE @ 1 kg a.i. ha^{-1} + straw mulch @ 3 t ha^{-1}
6.	T_6	Pendimethalin PE @ 1 kg a.i. ha^{-1} + straw mulch @ 5 t ha^{-1}
7.	T_7	Two hand weedings at 15-20 and 30-35 DAT
8.	T_8	Three hand weeding at 15-20, 30-35 and 45-50 DAT
9.	T_9	Weedy check
10.	T_{10}	Weed free

PE = pre-emergence, @ = at the rate, a.i. = active ingredient, ha = hectare, DAT = days after transplanting, PoE = post-emergence, T_1-Pendimethalin PE @ 1 kg a.i. ha^{-1} + mechanical weeding at 30-35 DAT, T_2-Quizalofop ethyl PoE @ 50 g a.i. ha^{-1} + mechanical weeding at 30-35 DAT, T_3- Pendimethalin PE @ 1 kg a.i. ha^{-1} + Quizalofop ethyl PoE @ 50 g a.i. ha^{-1}, T_4-Pendimethalin PE @ 1 kg a.i. ha^{-1} + Quizalofop ethyl PoE @ 50 g a.i. ha^{-1} + mechanical weeding at 30-35 DAT, T_5-Pendimethalin PE @ 1 kg a.i. ha^{-1} + straw mulch @ 3 t ha^{-1}, T_6-Pendimethalin PE @ 1 kg a.i. ha^{-1} + straw mulch @ 5 t ha^{-1}, T_7- Two hand weeding at 15-20 and 30-35 DAT, T_8-Three hand weeding at 15-20, 30-35 and 45-50 DAT, T_9- Weedy check, T_{10}- Weed free

2.3 Observations

2.3.1 Growth parameters

Leaf area index (LAI); Total number of the functional leaves obtained from the plant sampled for dry matter studies were graded into three sizes (small, medium and large) and representative leaf from each category was taken for measurement with the help of leaf area meter. The total leaf area of individual category multiplied by the total number of leaves in that category gave the total leaf area. Leaf area index is the ratio between leaf area to ground area.

$$\text{LAI} = \frac{\text{Leaf area } (\text{cm}^2)}{\text{Ground area } (\text{cm}^2)}$$

Crop growth rate (CGR); Crop growth rate indicates at what rate the crop is growing *i.e.* whether the crop is growing at a faster rate or slower rate than normal. It is expressed as gram of dry matter produced per day. Crop growth rate was calculated by the following formula and expressed as g/day/m^2 (Watson, 1952) [10].

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

Where w_1 and w_2 are dry weight of plants at time t_1 and t_2, respectively.

Relative growth rate (RGR); This parameter indicates rate of growth per unit dry matter. It is similar to compound interest, wherein interest is also added to the principal to calculate interest. It is expressed as gram of dry matter produced by a gram of existing dry matter in a day. Relative growth rate calculated by the following formula and expressed as mg/g/day (Blackman, 1919) [1].

$$\text{RGR } (\text{g}/\text{g}/\text{day}) = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1}$$

Where w_1 and w_2 are dry weight of plants at time t_1 and t_2, respectively.

2.3.2 Yield

The crop was harvested at 90 days after transplanting or at initiation of flowering; net plot of every treatment was harvested separately with help of sickle and kept in threshing floor under shade for drying the herb after taking the fresh weight of harvested every net plot. After complete drying of plants, dry weight was also taken to calculate dry herbage yield of net plot and accordingly yield (t/ha).

3 Results and Discussion

3.1 Growth Parameters

3.1.1 Leaf Area Index (LAI)

Maximum leaf area index was observed in weed free treatment which was significantly higher than all other weed management treatments. The lowest leaf area index was observed in weedy check treatment which was significantly lower than all other weed management treatments at 30 DAT, but statistically equivalent with T_1 (Pendi. PE @ 1 kg a.i./ha + MW at 30-35 DAT), T_2 (Quizalofop ethyl PoE @ 50 g a.i./ha + MW at 30-35 DAT), T_3 (Pendi. PE @ 1 kg a.i./ha + Quizalofop ethyl PoE @ 50 g a.i./ha) and T_5 (Pendi. PE @ 1 kg a.i./ha + straw mulch @ 3 t/ha) treatments at 60 DAT The maximum LAI was recorded in weed free treatment. It was mainly due to effective control of weeds at all stages of crop growth with created favourable environment for plant growth resulted in increased leaf area and LAI. After weed free treatment, second maximum LAI was observed in T_8 (Three hand weeding) treatment at all stages of crop growth. It was mainly due to weeds were effective controlled by three hand weedings than all other herbicide and mulching methods.

Similar results were also obtained by Tamang *et al.* (2014) [8]. The lowest LAI was observed in weedy check treatment. It was mainly due to uncontrolled weeds which increased weed density per unit area which increased inter and intra competition in crop and weed plants for nutrients, moisture and space resulting in decreased leaf area and LAI.

3.1.2 Crop growth rate (CGR)

Crop growth rate increased with increasing crop age and varied significantly due to different weed management treatments at various stages of crop growth. In general, initially, CGR increased at slower rate up to 30 DAT and thereafter the rate increased as increasing rate and reached its peak between 30 to 60 DAT and thereafter crop growth rate decreased gradually between 60 to 90 DAT. Maximum crop growth rate at 30-60 DAT (8.517 g/m^2/day) and 60-90 DAT (6.310 g/m^2/day) was recorded in weed free treatment which was significantly higher than all other treatments, except T_8 (Three hand weeding) treatment. No significant difference was observed in CGR in weedy check, T_1 (Pendi. PE @ 1 kg a.i./ha + MW at 30-35 DAT), T_5 (Pendi. PE @ 1 kg a.i./ha + straw mulch @ 3 t/ha) and T_7 (Two hand weeding) treatments at 60-90 DAT. Significantly higher CGR was recorded in T_6 (Pendi. PE @ 1 kg a.i./ha + straw mulch @ 5 t/ha) treatment than T_5 (Pendi. PE @ 1 kg a.i./ha + straw mulch @ 3 t/ha) treatment at 60-90 DAT, but no significant difference was observed at 30-60 DAT. Maximum CGR was observed in weed free treatment. It was mainly due to all weeds were effectively controlled in weed free treatment by repeated hand weedings which significantly increased CGR. Similar results were also obtained by **Gupta *et al.* (2014).** The lowest growth rate was recorded in weedy check treatment at 30-60 DAT. It was mainly due to heavy infestation of weeds in weedy check which causes suppression of crop plants.

3.1.3 Relative growth rate (RGR)

Relative growth rate increased with increasing crop age and varied significantly due to different weed management treatments at various growth stages of crop. At 30-60 DAT, maximum relative growth rate (62.437 mg/g/day) was observed in T_8 (Three hand weeding) treatment which was significantly higher than all other treatments, except weed free, T_1 (Pendi. PE @ 1 kg a.i./ha + MW at 30-35 DAT), T_4 (Pendi. PE @ 1 kg a.i./ha. + Quizalofop ethyl PoE @ 50 g a.i./ha + MW at 30-35 DAT), T_5 (Pendi. PE @ 1 kg a.i./ha + straw mulch @ 3 t/ha) and T_6 (Pendi. PE @ 1 kg a.i./ha + straw mulch @ 5 t/ha) treatments which was statistically at par. The lowest relative growth rate (33.333 mg/g/day) was observed in weedy check treatment which was significantly lower than all other treatments. The maximum relative growth rate at 60-90 DAT was observed in weed free treatment. It was mainly due to all weeds were effectively controlled by repeated hand weedings, which providing optimum conditions for crop growth which increased RGR. The minimum relative growth rate at 30-60 DAT was obtained in weedy check treatment. It was mainly due to uncontrolled weeds which increased in plant population per unit area in weedy check treatment, resulted decrease relative growth rate.

Table 2: Leaf area index, crop growth rate (g/m^2/day) and relative growth rate as influenced by different weed management treatments at various stages of crop growth

Treatments	LAI			CGR (g/m^2/day)		RGR (mg/g/day)	
	30 DAT	60 DAT	90 DAT (Harvest)	30-60 DAT	60-90 DAT	30-60 DAT	60-90 DAT
T_1	0.431	0.778	1.789	6.290	1.947	57.013	7.553
T_2	0.341	0.656	1.667	3.330	2.170	46.277	13.310
T_3	0.327	0.592	1.176	2.880	2.360	45.833	15.883
T_4	0.695	1.568	2.937	7.163	2.523	59.393	8.563
T_5	0.331	0.627	1.354	4.180	1.850	60.530	8.593
T_6	0.409	0.811	1.671	4.330	2.927	57.747	14.733
T_7	0.582	1.234	2.005	5.130	1.200	49.237	5.530
T_8	0.757	2.092	3.060	8.103	5.080	62.437	14.033
T_9	0.266	0.520	1.122	1.220	0.980	33.333	10.057
T_{10}	0.823	3.391	3.944	8.517	6.310	61.720	16.133
SE(m)±	0.011	0.088	0.108	0.155	0.345	2.920	4.787
CD (P=0.05)	0.032	0.264	0.322	0.465	1.032	8.744	N/A

4.2.7 Dry and fresh herbage yield

The data recorded on dry and fresh herbage yield at 90 DAT (harvest) are presented in Table 3. Dry matter accumulation of crop plants increased with advanced of crop age and reached maximum at 90 DAT (harvest) Wagner and Nadasy (2006) [9]. All the treatments significantly increased fresh herbage yield as compared to weedy check treatment. Maximum fresh herbage yield (25.070 t/ha) was recorded in weed free treatment which was significantly higher than all other treatments, except T_8 (Three hand weeding) treatment which was statistically at par. The lowest fresh herbage yield (7.547 t/ha) was recorded in weedy check treatment which was significantly lower than all other treatments, except T_3 (Pendi. PE @ 1 kg a.i./ha + Quizalofop ethyl PoE @ 50 g a.i./ha) treatment which was statistically equivalent.

No significant difference was observed in fresh herbage yield in T_1 (Pendi. PE @ 1 kg a.i./ha + MW at 30-35 DAT) and T_2 (Quizalofop ethyl PoE @ 50 g a.i./ha + MW at 30-35 DAT) treatment. After weed free treatment, fresh herbage yield was significantly higher in T_8 (Three hand weeding) treatment than all other treatments, except T_1 (Pendi. PE @ 1 kg a.i./ha + MW at 30-35 DAT) and T_4 (Pendi. PE @ 1 kg a.i./ha. + Quizalofop ethyl PoE @ 50 g a.i./ha + MW at 30-35 DAT) treatment which was statistically at par. The maximum dry biomass yield (4.693 t/ha) was recorded in weed free treatment which was significantly higher than all other treatments. The lowest dry biomass yield (1.437 t/ha) was recorded in weedy check treatment which was significantly lower than all other treatments, except T_3 (Pendi. PE @ 1 kg a.i./ha + Quizalofop ethyl PoE @ 50 g a.i./ha) and T_2 (Quizalofop ethyl PoE @ 50 g a.i./ha + MW at 30-35 DAT) treatment. After weed free treatment, dry biomass yield was significantly higher in T_8 (Three hand weeding) treatment than all other treatments, except T_4 (Pendi. PE @ 1 kg a.i./ha. + Quizalofop ethyl PoE @ 50 g a.i./ha + MW at 30-35 DAT) treatment. Statistically no significant difference was observed in dry biomass yield in T_5 (Pendi. PE @ 1 kg a.i./ha + straw

mulch @ 3 t/ha) and T_6 (Pendi. PE @ 1 kg a.i./ha + straw mulch @ 5 t/ha) treatment.

Maximum dry and fresh herbage yield was observed in weed free treatment (Kumar and Kumar, 2013) [6]**.** It was mainly due to effective control of all weeds in weed free treatment by repeated hand weedings at various stages of crop growth which significantly increased dry and fresh biomass yield. Similar results were also obtained by Gupta *et al.* (2014) [4]**.** The lowest dry and fresh herbage yield was recorded in weedy check treatment. It was mainly due to uncontrolled weeds situation resulted heavy infestation of weeds which suppressed of crop plants and decreased fresh and dry biomass yield.

Table 3: Fresh and dry biomass yield (t/ha) as influenced by different weed management treatments at harvest

Treatments	Fresh biomass yield (t/ha)	Dry biomass yield (t/ha)
T_1: Pendi. PE @ 1 kg a.i./ha + MW at 30-35 DAT	15.813	2.823
T_2: Quiza. PoE @ 50 g a.i./ha + MW at 30-35 DAT	14.940	2.000
T_3: Pendi. PE @ 1 kg a.i./ha + Quiza. PoE @ 50 g a.i./ha	12.027	1.863
T_4: Pendi. PE @ 1 kg a.i./ha. + Quiza. PoE @ 50 g a.i./ha + MW at 30-35 DAT	17.163	3.307
T_5: Pendi. PE @ 1 kg a.i./ha + straw mulch @ 3 t/ha	13.997	2.343
T_6: Pendi. PE @ 1 kg a.i./ha + straw mulch @ 5 t/ha	14.217	2.627
T_7: Two HW at 15-20 & 30-35 DAT	15.347	2.343
T_8: Three HW at 15-20, 30-35 & 45-50 DAT	20.640	3.817
T_9: Weedy check	7.547	1.437
T_{10}: Weed free	25.070	4.693
SE(m)±	1.633	0.230
CD (P=0.05)	4.890	0.689

Conclusion

On the basis of experimental results, it could be concluded that the treatment T_4 (Pendimethalin PE @ 1 kg a.i./ha. + Quizalofop ethyl PoE @ 50 g a.i./ha followed by mechanical weeding) may be taken as an alternative to the hand weeding for efficient weed control and achieving high biomass yield of kalmegh during *kharif* season.

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