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Research Article

Influence of harvesting stages and drying methods on growth, yield and quality of black night shade (*Solanum nigrum* L.)

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ABSTRACT

In commercial cultivation of medicinal plants, management of harvesting stages and post harvest handling play a very deciding role in the quality of the end product. Hence, a trial was conducted to study the influence of different harvesting stages and drying methods on growth, yield and alkaloid content of black night shade (*Solanum nigrum* L.) in both the main crop and the ratoon crop. The experiment was conducted at the Department of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bengaluru, Karnataka. The experiment was laid out in Randomized complete block design for field experiment and factorial CRD for lab experiments. The treatments comprised of four harvesting stages (100% flowering stage, fruiting stage, mature green berry stage and berry ripening stage) and three drying methods (sun drying, shade drying and tray drying). The maximum plant height (129.1 cm), number of branches (145.9 plant^{-1}), plant spread (12931 sq cm) and dry matter (214.1 g plant^{-1}) were recorded in plants harvested at berry ripening stage. However, the highest number of leaves, maximum cumulative fresh (36.93 t ha^{-1}) and dry herbage yield (7.62 t ha^{-1}) were obtained from plants harvested at green berry stage which also resulted in maximum alkaloid content (1.02 %). Drying of the harvested produce under shade was found to be beneficial in obtaining higher alkaloid content (1.07%) and alkaloid yield (85.63 kg ha^{-1}) of the final produce. Hence, harvesting black night shade at mature green berry stage and drying the harvested produce under shade was found ideal to realize maximum fresh and dry herb yield as well as alkaloid content and yield per hectare.

Keywords: Black night shade, *Solanum nigrum*, harvesting stages, drying methods, alkaloid content

INTRODUCTION

Black night shade (*Solanum nigrun* L.) is a medicinal herb belonging to the family Solanaceae, in which, the leaves, berries and the whole herb are medicinally important. The herb is known to contain steroidal glyco-alkaloids like α-solanigrine, β-solanigrine, solamargine and solasodine. The total alkaloid content of the fruits and leaves is 0.101 and 0.431 per cent, respectively (Varshney and Sharma, 1965). The herb has antiseptic, anti-dysenteric, antispasmodic, emollient, diuretic, laxative, cathartic and narcotic properties (Kirthikar and Basu, 1975). It is an important upcoming medicinal crop which has great demand from phyto-pharmaceutical industries and is used for manufacturing commercial *ayurvedic* formulations *viz*., *Actilivforte, Geriforte, Herbolax, Manol, Liv-52, Galactin Vet, Geriforte vet, Liv-52 vet* and *Eve care.*

In commercial cultivation of medicinal and aromatic plants, an in-depth knowledge of growth and development phenomenon of the plant is necessary to obtain consistence and rich bioactive end products. Knowledge of the growth stages of medicinal plants regarding accumulation of active principles plays a very deciding role in successful cultivation. The raw material of different botanicals is to be harvested at proper season and different growth stage keeping in view its correlative relationship with plants and their organs (Gill and Randhawa, 1992; Singh *et al.*, 2002). It varies from species to species and hence, plants need to be

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harvested at appropriate stage of maturity so as to maintain balance between the herbage yield and the alkaloid content for maximizing the alkaloid yield.

Similarly, post-harvest handling of the harvested herb is also equally important. Most of the harvested material in its fresh form contains 60-90 per cent moisture and therefore, liable to quantitative as well as qualitative physiological/ microbial degradation affecting the active principle content and quality of the produce (Chatterjee, 2002). Hence, appropriate processing or drying methods are necessary to retain the active principle content in the harvested produce and hence present investigation was carried out to find out the appropriate stage of harvesting and drying methods in Black night shade.

MATERIALS AND METHODS

The investigation was carried out at the Department of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru. The experimental site is located at an elevation of 930 m above MSL, latitude of 12°51' N and longitude of 77° 35' E with true tropical climate with an average relative humidity of 60 per cent. The rainfall received during the cropping period was 90 mm. The maximum and minimum temperatures were 25.07° C and 17.77° C, respectively. Mean relative humidity was 60 per cent and the average period of sunshine was 5.15 hours. The experimental site was fairly level with red sandy loam soil with 7.1 pH, 0.2 m mhos cm^{-2} EC, 0.34 per cent organic carbon, 206.4 kg ha^{-1} nitrogen, 25.3 kg ha^{-1} phosphorus and 180.8 kg ha^{-1} potassium.

The nursery was raised during *kharif* season in seed pans and 30 day old seedlings were transplanted in the experimental plots at 45×30 cm spacing. The recommended dose of FYM (10 t ha^{-1}) was applied a month before transplanting and NPK (100:50:50 kg NPK ha^{-1}) were applied in the form of urea, super phosphate and muriate of potash. Full dose of P, K and 50 per cent N were supplied as basal dose and remaining 50 per cent N was applied as top dressing at 30 days after transplanting. The observations on growth and yield parameters were recorded periodically. The crop was harvested at different growth stages as per the treatments by cutting the plants at 15 cm above the ground level. The field experiment was laid in Randomized Complete Block Design comprising of four harvesting stages, *viz.* 100 per cent flowering stage (H_1), fruiting stage (H_2), mature green berry stage (H_3) and berry ripening stage (H_4). The harvested produce was dried by three methods of drying *viz.*, sun drying (D_1), shade drying (D_2) and tray drying (D_3). The lab experiments were carried out in factorial CRD with three replications. The main crop was harvested at 100 per cent flowering stage i.e., at 30 days after transplanting (DAT), fruiting stage at 45 DAT, mature green berry stage at 70 DAT and at berry ripening stage at 90 DAT. After harvesting the main crop, the stumps were allowed for ratooning by applying 50 per cent of the recommended dose of fertilizer. The ratoon crop was earthed up and irrigated regularly. The ratoon crop was harvested at 50, 75 and 120 days after harvesting (100 per cent flowering, fruiting and mature green berry stage, respectively) whereas; ratooning was not possible from the clumps harvested at berry ripening stage. Harvested produce was shade dried by spreading it indoors in thin layer on clean concrete floor, while, for sun drying the samples were kept in aluminum trays under sun with occasional upturning. The samples pertaining to tray drying were dried in hot air oven at 45°C±1°C. The samples of the dried herb were analyzed for total alkaloid content using gravimetric method (Annon., 2003). The data was analyzed as underlined by Sundararaj *et al.* (1972).

RESULTS AND DISCUSSION

Growth parameters

Observations on different growth parameters *viz*., plant height, number of branches, plant spread and number of leaves recorded at harvest were significantly influenced by different stages of harvesting (Table 1). The main crop which was harvested at berry ripening stage (H_4) recorded the maximum plant height (129.1 cm), number of branches (145.9) and plant spread (12931 cm^2). All these parameters were recorded least in the crop harvested at 100 per cent flowering stage (H_1). The increase in vegetative parameters from flowering to fruiting stage might be due to the indeterminate growth habit of the plant as reported by Gill and Randhawa (1992) and Ahmed *et al.* (2002). While, in ratoon crop, the maximum plant height (102.7 cm), number of branches/plant (43.7) and plant spread (4438 cm^2) were observed in the crop at mature green berry stage (H_3). This also indicates that the harvested stumps of the main crop retained vigour to produce good vegetative growth in the subsequent ratoon crop only up to mature green berry stage. The number of leaves per plant was maximum (636.9 and 117.6 in main and ratoon crops, respectively) at mature green berry stage and decreased at berry ripening stage (619 $plant^{-1}$) in the main crop and at 100 per cent flowering stage (95.7 $plant^{-1}$) in the ratoon crop. There was reduction in the number of leaves per plant from mature green berry stage to berry ripening stage as delay in harvesting led to senescence and withering of the older leaves (Singh *et al.*, 1995; Balyan and Sobti, 1990).

Dry matter accumulation in different plant parts *viz.* stem, leaf and berries was significantly influenced due to different harvesting stages (Table 2). Dry matter accumulation in stems

Table 1: Influence of stage of harvest on growth parameters of main and ratoon crops in Black night shade (*S. nigrum* L.)

Treatments	Plant height (cm)		No. of branches plant^{-1}		Plant spread (cm^2)		No. of leaves plant^{-1}	
	Main crop	Ratoon crop	Maincrop	Ratoon crop	Main crop	Ratoon crop	Main crop	Ratoon crop
H_1	53.7	45.1	14.2	11.7	2692	2302	98.9	95.7
H_2	82.1	72.3	27.0	31.7	3597	3493	247.9	111.0
H_3	104.9	102.7	70.7	43.7	8054	4438	636.9	117.6
H_4	129.1	-	145.9	-	12931	-	619.0	-
S Em±	0.8	0.8	0.8	0.2	74	50	2.0	8.1
CD @ 5%	2.3	2.4	2.3	0.6	215	150	5.9	24.4

H_1 – 100% flowering stage; H_2 – Fruiting stage; H_3 – Mature green berry stage; H_4 – Berry ripening stage

Table 2: Influence of stage of harvest on dry matter accumulation (g/plant) in the main crop of Black night shade (*S. nigrum* L.)

Harvesting stages	Leaves	Stem	Berries	Total
H_1	16.5	22.7	0.00	39.1
H_2	34.7	64.1	61.4	160.2
H_3	65.3	80.4	65.4	211.5
H_4	63.3	91.5	59.4	214.1
S Em±	1.2	1.3	1.0	1.8
CD @ 5%	3.6	3.8	2.9	5.3

H_1 – 100% flowering stage; H_2 – Fruiting stage; H_3 – Mature green berry stage; H_4 – Berry ripening stage

was maximum (91.5 g plant^{-1}) when the crop was harvested at berry ripening stage (H_4), which could be attributed to more number of branches at this stage. In case of leaves and berries, it was maximum at mature green berry stage (65.3 g plant^{-1} and 65.4 g plant^{-1}, respectively). Maximum dry matter accumulation in leaves and berries at mature green berry stage might be due to the fact that more number of leaves and berries were present at this stage while, at berry ripening stage dry matter accumulation was lower due to shedding of older leaves and over ripe berries. These results corroborate the findings of Ahmed *et al.* (2002) in *Catharanthus roseus*. Berry ripening stage (H_4) recorded highest dry matter accumulation per plant (214.1g), which might be due to the increase in stem and berry weight at berry ripening stage due to the longer period available for its physiological growth (Seema *et al.,* 2002).

Yield parameters

The maximum fresh (26.2 and 13.85 t ha^{-1}) and dry herbage yield (5.18 t ha^{-1}and 2.64 t ha^{-1}) in the main and ratoon crop was recorded at berry ripening stage and mature green berry stage (Table 3). While, it was minimum when the crop was harvested at 100 per cent flowering stage (H_1). The higher fresh herb yield registered at berry ripening stage could be attributed to the longer growth period which helped in producing taller plants with more number of branches (Singh *et al.,* 1995; Farooqi and Sreeramu, 2006). However, the maximum cumulative fresh herbage yield (36.93 t ha^{-1}) was recorded in mature green berry stage (H_3) compared to berry ripening stage (H_4) as no ratoon crop was obtained when the crop was harvested at berry ripening stage. The crop might have lost its vigour or rejuvenating capacity when harvested at berry ripening stage. Higher cumulative dry herb yield

Table 3: Influence of stage of harvest on fresh and dry herbage yield (t ha^{-1}) in Black night shade (*S. nigrum* L.)

Treatments	Main crop		Ratoon crop		Cumulative	
	Fresh herbage yield	Dry herbage yield	Fresh herbage yield	Dry herbage yield	Fresh herbage yield	Dry herbage yield
H_1	6.22	1.19	3.04	0.62	9.27	1.81
H_2	17.01	3.44	5.32	1.13	22.33	4.57
H_3	23.08	4.98	13.85	2.64	36.93	7.62
H_4	26.17	5.18	-	-	26.17	5.18
S Em±	0.22	0.06	0.32	0.07	0.5	0.08
CD @ 5%	0.66	0.19	0.98	0.20	1.07	0.24

Harvesting stages
H_1 – 100% flowering stage; H_2 – Fruiting stage
H_3 – Mature green berry stage; H_4 – Berry ripening stage

Drying methods
D_1- Sun drying; D_2- Shade drying
D_3- Oven drying

(7.62 t ha^{-1}) was also obtained at mature green berry stage, as the plants harvested at berry ripening stage did not respond to ratooning. Similarly, in indigo *(Indigofera tinctoria*), the crop harvested at little pod stage recorded 20 per cent higher biomass and 46 per cent higher dye content compared to crop harvested at flowering stage (Pratibha and Korwar, 2005).

Quality parameters

Stages of harvest and drying methods significantly influenced the alkaloid content (Figure 1) and alkaloid yield (Table 4) as there was a steady increase in total alkaloid content from 100 per cent flowering stage to mature green berry stage. Similar results were observed in *Catharanthus roseus, Datura metel, Solanum indicum,* and *Dioscorea floribunda*, wherein the active principles were maximum during reproductive phase and harvests are generally made when nearly 60-70 per cent of the reproductive phase is completed (Chatterjee, 2002). In *Costus speciosus* initiation of reproductive phase registers maximum diosgenin content (Chatterjee, 2002). In most perennially grown medicinal plant species, maximum attainment of active principles takes place after 3-4 years (in some cases like *Cinchona* during 7-8th year) and optimum period of harvest is determined accordingly (Chatterjee, 2002). The crop harvested at mature green berry stage and shade dried recorded the highest alkaloid content (1.07% w/w) and the least was in the crop harvested at 100 per cent flowering stage and dried under sun. The sun dried produce had the lowest alkaloid content irrespective of the stage of harvest. This might be due to

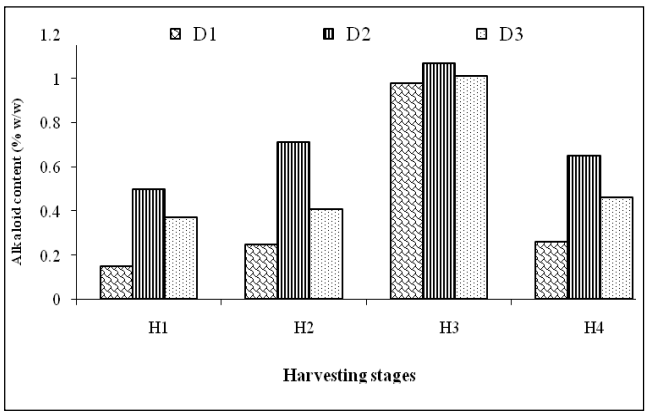

Figure 1: Influence of harvesting stages and drying methods on alkaloid content in whole dry herb (%w/w) of Black night shade (*S. nigrum* L.)

Harvesting stages
H_1 – 100% flowering stage
H_2 – Fruiting stage
H_3 – Mature green berry stage
H_4 – Berry ripening stage

Drying methods
D_1- Sun drying
D_2- Shade drying
D_3- Oven drying

Table 4: Influence of harvesting stages and drying methods on total alkaloid yield (kg ha^{-1}) in Black night shade (*S. nigrum* L.)

Treatment	D_1	D_2	D_3	Mean
H_1	2.81	6.74	6.51	5.35
H_2	10.77	33.06	19.45	21.09
H_3	74.97	85.63	72.75	77.79
H_4	12.93	34.60	24.17	23.90
Mean	25.37	40.01	30.72	32.03
	SEm±	CD @ 5%		
H	0.72	2.12		
D	0.63	1.84		
HXD	1.25	3.68		

Harvesting stages
H_1 – 100% flowering stage
H_2 – Fruiting stage
H_3 – Mature green berry stage
H_4 – Berry ripening stage

Drying methods
D_1- Sun drying
D_2- Shade drying
D_3- Oven drying

deterioration of plant constituents when exposed to direct sun. Oven dried produce (45°C ± 1°C) also yielded lesser alkaloid content compared to shade dried ones which might be due to the damage caused to the plant tissues when exposed to high temperature (Leela and Angadi, 1992). The highest alkaloid yield (77.79 kg ha^{-1}) was recorded in the crop harvested at mature green berry stage and least was in 100 per cent flowering stage (5.35 kg ha^{-1}). The highest alkaloid recovery in mature green berry stage (H_3) is mainly due to higher cumulative dry herb yield coupled with higher alkaloid content obtained in this treatment (Gill and Randhawa, 1992). Different drying methods significantly influenced the alkaloid yield per hectare (Table 4). The maximum alkaloid yield (40.01 kg ha^{-1}) was recorded in shade dried herbage as shade drying leads to lower chemical degradation of the produce compared to sun and oven drying (Farooqi and Sreeramu, 2006). By the time the crop reaches berry ripening stage, leaves attain senescence and start withering which in turn reduces the alkaloid yield of the produce. Apart from this, as the age of the plant advances the plant's vigour and rejuvenation capacity gets reduced, resulting in failure to produce ratoon crop when the crop was harvested at berry ripening stage. This in turn resulted in lower cumulative dry herb as well as alkaloid yield per hectare at berry ripening stage.

CONCLUSION

Our results revealed that harvesting Black night shade at mature green berry stage and shade drying of the harvested produce would be ideal to realize maximum fresh and dry herb yield, alkaloid content and alkaloid yield per hectare.

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