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Effect of spacing, environmental changes and date of sowing on morphology, life cycle, growth, yield and quality of Ashwagandha (*Withania somnifera.* Dunal): A review

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Abstract
Herbal plants are considered as one of the most important source of medicines since the dawn of human civilization. *Withania somnifera* also known as Indian ginseng, Ashwagandha, Winter cherry, Ajagandha, Amukkuram in Malayalam and Samm Al Ferakh. Plant is with erect branching, wild herb. The cultivated plants are morphologically distinct from wild forms. Supplies of roots for medicinal purposes, is being done mostly from cultivated plants. Ashwagandha (*Withania somnifera.* Dunal) belongs to family *Solanaceae.* As plant spacing and date of sowing has a profound influence on the crop performance because it determines the kind of environmental conditions to which the various phenological stages of the crop are exposed. It affects various growth and biochemical parameters in ashwagandha. For quicker emergence, better growth and higher yield, crop growth should synchronize with optimum weather conditions like temperature, rainfall, light and relative humidity. Different meteorological parameters i.e. temperature, moisture, wind and the amount of sunlight are all components of the weather. Those are also the components needed for plant growth. Plants need water, oxygen and sunlight to grow, but it is the air temperature that regulates most of the plant processes – germination, flowering, photosynthesis, and respiration. Each plant has its own optimum, maximum and minimum temperature conditions for their growth and development. Thus effect of spacing, environmental changes and date of sowing on morphology, life cycle, growth, yield and quality of Ashwagandha (*Withania somnifera.* Dunal) is needed to review.

Keywords: *Withania somnifera.* Dunal, growth, yield, quality and medicinal plant

Introduction
Since the dawn of human civilization, herbal plants are considered as one of the most important source of medicines. According to one estimate of botanical survey of India, about 7,500 plants are used for medicinal purposes out of 15,000 plants of our country. There is a growing demand for medicines of Ayurveda, Siddha, Unani and Homeopathy both for domestic consumption and export purposes. Out of 80,000 tonnes of medicinal plants imported by Western countries, India tops the list of exporters to USA and Europe with a share of over 10,000 tonnes [1]. The values of trade in medicinal plants are about Rs. 5,000 crores, while the world trade is about US $ 62 billion. India exports herbal products and medicines to the tune of Rs. 550 crores annually [2]. A survey indicated that the use of herbal medicines will reach to the tune of US $ 5 trillion during 2050 [3]. Currently, the Ayurvedic and herbal products turnover is estimated to be Rs. 25,000 crores.

The increasing demand for medicinal plant products is much felt by the people and the diversified agro-climate of India is a boon for cultivation and is rightly called the botanical garden of the world. India officially recognized over 3000 plants for their medicinal value. India being one of the 12 mega diversity centers in the world, with this bio-resource wealth, it ranks 10th in the world and 4th in Asia having 15 to 20 thousand plants species with medicinal value of which 30 per cent are considered as endemic to India. Currently, there are about 880 species of medicinal plants in all India trade [1]. Among the various medicinal plants, *Withania somnifera.* Dunal (Winter cherry, Ashwagandha or Asgandh) is an important medicinal plant and its use in Ayurvedic and unanisystems of medicine extends back over 3000 to 4000 year.

Ashwagandha (*Withania somnifera.* Dunal) belongs to family *Solanaceae* and it attains a height of about 170 cm.

The fruits or berries are smooth, spherical, red coloured with 6 mm diameter enclosed in an inflated and membranous calyx. The fruit has small kidney shaped yellow coloured seeds [4]. Ashwagandha is native to the dry regions of south central Asia, and thrives in a Mediterranean-type climate. It is a stout shrub. It grows prolifically in India, Nepal, Pakistan, Srilanka and Bangladesh. Organic Ashwagandha is known as *Indian Ginseng***,** although the plant has no relationship with actual Ginseng plant native to north eastern Asia. Its use in India's Ayurvedic System of Medicine is as important as is of Ginseng use in Traditional Chinese Medicine System. The species name *somniferous* means *sleep - inducing* in Latin, indicating that it has sedating properties.

Withania somnifera also known as Indian ginseng, Ashwagandha, Winter cherry, Ajagandha, Amukkuram in Malayalam and Samm Al Ferakh. Plant is with erect branching, wild herb. The cultivated plants are morphologically distinct from wild forms. Supplies of roots for medicinal purposes, is being done mostly from cultivated plants. Entire plant is uprooted for collection of roots. This crop is generally taken in late *kharif* season only on conserved soil moisture and can be grown on any type of soils having good drainage with 7.5 to 8.0 pH. It requires dry climate for better growth and root development but winter temperatures are known to improve the root quality [5]. The areas receiving 67-75 cm rainfall are best suited for its cultivation. Ashwagandha root contains 0.4 – 1.2 per cent alkaloids, 40 - 65 per cent starch, 40 - 65 per cent fibers and minor quantity of oil. The important chemical constituents are alkaloids (Withanolides) that are present in roots, leaf and berries [6]. Main active constituents are 'somniferum', 'withananine'. Several preparations related to nervous systems contain the drug of this plant. Roots yield important drugs useful in all types of skin lesions, paralytic conditions, ulcers, in reducing pus formation and in rheumatic pain inflammation of joints. *Ashwagandha* in Sanskrit means "horse's smell," probably originating from the odor of its root which resembles that of horse's sweat.

As date of sowing has a profound influence on the crop performance because it determines the kind of environmental conditions to which the various phenological stages of the crop are exposed. It affects various growth and biochemical parameters in ashwagandha. Harmonious balance of vegetative and reproductive phases for successful crop production has been stressed. For quicker emergence, better growth and higher yield, crop growth should synchronize with optimum weather conditions like temperature, rainfall, light and relative humidity. Though the ashwagandha is drought hardy, the winter temperatures favour root development and improves the withanolide content in the roots [5].

Different meteorological parameters i.e. temperature, moisture, wind and the amount of sunlight are all components of the weather. Those are also the components needed for plant growth. Plants need water, oxygen and sunlight to grow, but it is the air temperature that regulates most of the plant processes – germination, flowering, photosynthesis, and respiration. Each plant has its own optimum, maximum and minimum temperature conditions for their growth and development. The growth rate of many plants increases as the temperature increases although high air temperature also increases the loss of moisture from soil and from plants (evapotranspiration). Temperature affects plant growth as: i) Photosynthesis: Increases with temperature to a point, ii) Respiration: Rapidly increases with temperature. iii) Transpiration: Increases with temperature. iv) Flowering: May be partially triggered by temperature. v) Dormancy: Warmth, after a period of low temperature, will break dormancy and the plant will resume active growth. Humidity also controls the growth and geographical distribution of plants. Plants with high water requirement or transpiration ratio are limited to habitats where the supply of moisture is adequate. Wind velocity and sun shine hour also affect transpiration and photosynthesis directly and hence regulate growth of plants [7].

Ashwagandha (*Withania somnifera.* Dunal) is an important medicinal plant with a number of valuable medicinal uses. Ashwagandha is also known as 'Indian Ginseng' because of similarity between the properties of Ashwagandha roots and restorative properties of Ginseng roots. Distribution of this plant differs in different regions in India. It is generally distributed in drier parts of India, ascending to 5500 ft. in the Himalayas [7]. Being an important medicinal plant cultivated only in north-western regions of M.P. on about 4000 hectares of land.

1.1. History and status of Ashwagandha.
1.2. Morphology and life cycle.
1.3. Response to spacing
1.4 Responses to date of sowing (Panchang and Non-panchang)

History and status of Ashwagandha.

Ashwagandha (*Withania somnifera.* Dunal) is used in Indian traditional medicine. According to that report, in Ayurveda the roots of Ashwagandha are attributed with properties of health maintenance and restoration. The properties of Ashwagandha roots and restorative properties of ginseng roots are similar due to which Ashwagandha is called as 'Indian Ginseng**'**. They have also reviewed about the Ayurvedic preparations/formulations made from Ashwagandha, chemical constituents of various plant parts and biochemical activities of various constituents [8].

The ex-situ conservation of five important medicinal plants i.e. *Aloe barbadensis* (Ghee-kunwar), *Asparagus recemosus* (Satavari), *Costus speciosus* (Keu), *Rauvolfia serpentina* (Sarpagandha) and *Withania somnifera* (Ashwagandha) have already been declared in the category of threatened/rare species in Madhya Pradesh and Uttar Pradesh. A brief description of these plants with medicinal importance, conservation strategies, mode of multiplication etc. in experimental garden of Botanical Survey of India, Allahabad has been provided to encourage their conservation/multiplication [9].

Ashwagandha (*Withania somnifera*) is a multi-purpose medicinal plant offering solutions for a number of diseases and for restoration of healthy balance of life. Traditional uses and research results on biological activities of Ashwagandha have been reviewed here. Traditionally, Ashwagandha roots are used for nervousness, insomnia, weakness, anaemia, rheumatic pains, general debility and impotence and has abortificient, anodyne, bactericidal, contraceptive, emenagogual, narcotic, sedative, spasmolytic and tonic properties. Research has shown that the roots have anti-inflammatory, antioxidant, anticancer, tranquilizer, immunostimulatory, aphrodisiac, diuretic and adaptogenic uses [10].

Immunomodulatory activity of "ashwagandha churna", a reputed Ayurvedic herbal formulation based on *Withania somnifera*. The experimental paradigms used were cellular (foot pad swelling) immune responses to the antigenic challenge by sheep RBCs (SRBCs) and the neutrophil

adhesion test. On oral administration, ashwagandha churna showed a significant increase in neutrophil adhesion and delayed-type hypersensitivity response. It is concluded that ashwagandha churna significantly potentiated the cellular immunity by facilitating the footpad thickness response to SRBCs in sensitized rats [6].

Withania somnifera is a commonly used herb in Ayurvedic medicine. Although the review articles on this plant are already published, this review article is presented to compile all the updated information on its phytochemical and pharmacological activities, which were performed by widely different methods. Studies indicate ashwagandha possesses antioxidant, anxiolytic, adaptogen, memory enhancing, anti-parkinsonian, antivenom, antiinflammatory and antitumour properties [11]. Various other effects such as immunomodulation, hypolipidaemic, antibacterial, cardiovascular protection, sexual behavior, tolerance and dependence have also been studied. These results are very encouraging and indicate this herb should be studied more extensively to confirm these results and reveal other potential therapeutic effects. Clinical trials using Ashwagandha for a variety of conditions should also be conducted.

A study was conducted to create awareness among people on the proper use and collection of medicinal plants containing high levels of heavy metals and their adverse health effects. They stated that amount of heavy metals was determined in the medicinal plant *Withania somniferous* as well as in the soil it was grown in using atomic absorption spectrophotometer. The plant samples were collected from three different locations of NWFP, Pakistan. The plant parts including roots, stem, leaves and fruits were found to have the quantity of heavy metals corresponding to their content in the soil. Results showed that plants grown in contaminated areas have risk of having heavy metal concentrations beyond permissible limits compared to those growing in less contaminated areas [12].

Thangavel *et al.* [13] analyzed the protective effect of *Withania somnifera*, an indigenous medicinal herb used in Ayurvedic traditional systems for more than 3000 years in India, on gentamicin induced nephrotoxicity. The root extract of three different doses of *Withania somnifera* (viz., 250, 500, and 750 mg/kg) was administered orally to rats for 14 days before gentamicin induced nephrotoxicity treatment and thereafter concurrently with gentamicin induced nephrotoxicity (100 mg/kg) for 8 days. Nephrotoxicity was evident in gentamicin induced nephrotoxicity treated rats by significant increase in kidney weight, urea, creatinine, urinary protein, and glucose, and significant reduction in body weights and potassium, which was histopathologically confirmed by tubular necrosis.

Morphology and life cycle

Withania somnifera belongs to the family Solanaceae and the common name of this plant is Ashwagandha. Only two species *Withania somnifera* and *Withania coagulants* have been found so far. *Withania somnifera* is most sought species and is cultivated for medicinal purpose. *Withania somnifera* plants are erect, evergreen, herbaceous, tomentose shrubs and 130-150cm high. All its parts are clothed with whitish, stellate hairs. Branching is extensive, the leaf is ovate, entire and thin, its base is cuneate and is densely hairy beneath. The flowers are bisexual, greenish or yellow, axilary, in clusters about 25 forming umbellate cymes, sessile or sub-sessile.

The fruit is a berry, 7mm across, red, globose, smooth, and enclosed in an inflated, membranous and somewhat 5-angled, pubescent calyx. The fruit turn orange red in colour when they mature. The seeds are yellow in colour and reniform in shape. The flowering season is from July to September and ripe fruits are available in December. A variety Jawahar Asgandh-20 has been released from single plant section from the Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur Regional Agriculture Research Station, and Mandsaur (M.P.) [14]. This variety has recorded the highest dry root yield, consistently, over the others.

Response to spacing

A plant would perform better only when it is provided with optimum environmental conditions. The establishment of adequate plant population per unit area is most important to realize the full yield potential of a genotype. Variation in plant population has been found to affect growth and dry matter accumulation due to differential availability of light, moisture and nutrients. Higher plant densities restrict the growth of branches per plant and number of reproductive parts per plant but may be compensated by increased population densities. In ashwagandha roots are the economic part of the plant. The agronomic manipulations and practices aimed at improving the yield of roots through optimizing source – sink ratio is of more practical significance. The line sowing provides space for easy interculturing, weeding, fertilizer application and other inputs apart from uniform plant stand ultimately resulting in better growth and development of crop compared to broadcasting method of sowing [4]. The plant density to be used may depend on nature and fertility of soil. On the marginal land, the population is kept high [15].

Effect on growth and yield components

Spacing of different types affects the various growth and yield components of plants. Nigam *et al.* [16] carried out field trials for two years to study the spacing and its effect on root yield. In both the years broadcasting gave higher yields (5.02-733 q/ha) of dry roots than sowing in rows (4.12-6.83 q/ha) where plants were spaced at 30 x 5 to 45 x 10 cm. However, in another experiment where plants were spaced at 30 x 5 and 30 x 10 cm yielded 6.00 – 7.56 q/ha compared with 4.07-5.07 under wider spacing.

In a spacing trial at Coimbatore in coleus and reported that shoot weight per plant and tuber yield per plant were higher at wider spacing (60 cm x 30 cm) compared to closer spacing (60 cm x 20 cm) [17]. The effect of plant densities on growth and yield of coleus at Arabhavi (Karnataka) the plant height, plant spread in North- South and East-West directions, branches per plant, leaves per plant, lamina length and breadth of coleus were affected significantly by different plant densities [18]. Performance of diploid and induced autotetraploid *Solanum viarum* at varying plant densities was studied at Bangalore (Karnataka) and reported that number of berries per plant had inverse relation with plant densities but dry weight per plant was unaffected. Diploid and autotetraploid responded differently to varying plant densities for plant height, leaf length and breadth, petiole length, fruits per node and inter-nodal length [19].

Jayalakshmi [20] in a field experiment on coleus at Coimbatore under red sandy loamy soil, observed that all the growth parameters (plant spread, branches, leaf area, stem girth) and yield parameters (number of tuberous roots per plant, length and diameter) were found higher at wider spacing (60 cm x 60 cm) and lower at closer spacing (45 cm x 30 cm). The optimum spacing requirement for ashwagandha was studied by Agarwal Manish *et al.* [21] at Jobner on loamy sand soil.

They reported the longest roots at closer spacing (20 cm x 5 cm) compared to wider spacing (25 cm x 7.5 cm).

Effect on yield

Spacing also influences the yield of crops by affecting different growth phases of plants. An investigation on the spacing requirement of medicinal yam (*Dioscorea floribunda*) at Bangalore (Karnataka) reported that a spacing of 45 cm x 30 cm for one year crop and 60 cm x 45 cm for two years crop gave the highest tuber yield under irrigation [22]. In an experiment conducted on clayey alkaline soils of JNKVV, Mandsaur, Nigam *et al.* [16] observed significant increase in root yield of ashwagandha at higher plant density of 6.6 lakh per ha (30 cm x 10 cm) compared to 4.4 lakh per ha (45 cm x 5 cm) and 2.2 lakh per ha (45 cm x 10 cm).

The optimum spacing requirement for periwinkle was studied at Bangalore (Karnataka). A spacing of 45 cm x 15 cm recorded the highest root, leaf and stem yields. Wider spacing gave significantly lower yields [23]. While, in another experiment at Bhubaneswar, the highest tuber yield (501.61 q ha^{-1}) was obtained at 40 cm x 45 cm spacing though the tuber weight per plant was more at wider spacings [24]. At Mandsaur on medium black soils, Nigam and Kandalkar [4] found that the population of 8.0 lakh per ha (25 cm x 5 cm) was optimum for higher root yield of ashwagandha compared to wider spacings. In another study, the response of ashwagandha to plant density was found up to 15 lakh plants per ha [16].

In an experiment on planting density and spacing arrangement for higher berry yield in *Solanum viarum* at Bangalore (Karnataka). A linear relationship was found between planting density (up to 49,000 plants ha^{-1}) and berry yield in square spacing. The plant population within a range of 6900 to 28,000 plants per ha with rectangular spacing (East to West) proved superior to square spacing for getting higher berry yields. Planting in the direction of East to West helped in better light interception. The spacing requirement for *Solanum viarum* was studied by Reddy and Krishnan [25] at Bangalore (Karnataka). They found that both diploids and tetraploids gave increased berries yield (6216 kg ha^{-1}) at high plant density of 49,000 plants per ha compared to lower plant densities of 18,000 and 28,000 per ha. The results of an experiment conducted at Arabhavi (Karnataka) on the effect of different plant densities in Coleus indicated that the highest marketable tuber yield (13.86 t ha^{-1}) was recorded at 1,11,111 plants per ha and the lowest (7.70 t ha^{-1}) at 27,778 plants per ha [17].

Performance of diploid and induced autotetraploid *Solanum viarum* at varying plant densities resulted highest berry yield (9.95 t ha^{-1}) at higher density (1, 11, 000 plants ha^{-1}) [17]. In an experiment on sandy loam and light red soils at University of Agricultural Sciences, Bangalore, Farooqui and Sreenivas [26] reported that the optimum plant population was 20,000 to 25,000 per ha for harvesting higher root yield of ashwagandha. At Coimbatore on red sandy loam soils, reported the higher tuber yield of coleus at closer spacing (45 cm x 30 cm) and lower yield at wider spacing (60 cm x 60 cm) [20].

The production potential of traditional mono-cropping systems vis-à-vis monocropping of ashwagandha at low (100 x 103 plants ha^{-1}) and high (200 x 103 plants ha^{-1}) plant density levels indicated 53.8 per cent and 66.7 to 73.3 per cent more roots at high plant density levels than grown at low plant density under monocropping and overlapping systems respectively. They also reported that growing ashwagandha is more economical at both population densities in monocropping systems under moisture stressed rainfed conditions. Overlapping cropping of ashwagandha is suggested as a way to improve the productivity and economic returns from resource constrained rainfed agriculture in sub-tropical North India [27]. In another spacing trial, Chandrashekhar *et al.* [28] also found the higher tuber yield of coleus at closer spacing compared to wider spacing.

During rabi seasons of 2004 and 2005 at Agricultural Research Station, Annigeri, Karnataka, to study the effect of spacing and fertilizer levels on physiological parameters in relation to productivity of ashwagandha (*Withania somnifera Dunal)* in Vertisols. Sixteen treatments comprising 4 spacing (15 cm x 5 cm, 15 cm x 10 cm, 30 cm x 10 cm and 45 cm x 10 cm) and 4 fertilizer levels (control, 12 and 24, 18 and 36 and 24 and 48 kg N and P/ha) were undertaken in factorial design. A spacing of 15 cm x 10 cm proved superior over the other spacing in enhancing physiological parameters, viz., leaf area index (4.254), leaf area duration (80.6 days), net assimilation rate (0.404 g/dm2/day) and yield attributes resulting in increased dry root yield (1.42 tones/ha) [29].

Interaction of varieties and plant densities

In ashwagandha var. WS-20, the dry root yield (426 kg ha^{-1}) and seed yield (260 kg ha^{-1}) were significantly higher at plant density of 8 lakh per ha. While in ashwagandha var. WS-22, the highest root yield (492 kg ha^{-1}) and seed yield (312 kg ha^{-1}) were recorded at 6 lakh per ha [30].

Interaction of plant density and fertilizer

In a field experiment on clay alkaline soils at JNKVV, Mandsaur, Nigam *et al.* [16] observed that application of 30:30:0 kg N, P_20_5 and K_20 per ha to ashwagandha at plant density of 6.6 lakh per ha recorded significantly higher root yield (812 kg ha^{-1}) compared to 4.4 and 2.2 lakh per ha at same fertilizer level.

Effect on nutrient uptake

As nutrients are essential for growth and development of crop and spacing also affects the nutrient uptake by plant by changing its availability. In a spacing trial at Coimbatore on red sandy loam soils, Jayalakshmi [20] reported higher N, P and K content in tuberous roots of coleus in wider spacing (60 cm x 60 cm) than closer spacing (45 cm x 30 cm). While, closer spacing recorded the higher uptake of N, P and K (kg ha^{-1}) at 180 days after planting.

Economics

At Jobner (Madhya Pradesh), the highest net profit (Rs. 56,098 ha^{-1}) and B: C ratio (3.46) was obtained when ashwagandha was sown on 20th July at 20 cm x 7.5 cm spacing compared to other treatment combinations [31] whereas at Coimbatore realized the highest net returns (Rs. 82,192 ha^{-1}) and benefit: cost ratio (4.27) in closer spacing (45 cm x 30 cm) with 50 kg N per ha at 180 days after planting of coleus [19]. Growing ashwagandha proved to be more economical at high (200 x 103 plants ha^{-1}) and low (100 x 103 plants ha^{-1}) plant densities under mono-cropping and it is an ideal crop for moisture stressed rain fed conditions in subtropical North India [28].

Responses to date of sowing (Panchang and Non-panchang)

Date of sowing has a profound influence on the crop performance because it determines the kind of environmental

conditions to which the various phenological stages of the crop are exposed. For quicker emergence, better growth and higher yield, crop growth should synchronise with optimum weather conditions like temperature, rainfall, light and relative humidity. Harmonious balance of vegetative and reproductive phases for successful crop production has been stressed. Though the ashwagandha is drought hardy, the winter temperatures favours root development and improves the with anolide content in the roots [5].

The influence of organic manure and bio-regulators on growth and yield of ashwagandha with thirty treatment replicated twice in FRBD. The organic manure was applied basally. The bioregulators and micronutrients were sprayed at 30 days interval to the crop with a high-pressure sprayer. The yield contributing characters like root length, root diameter were observed under poultry manure + panchagavya combination. This led to higher root yield. The total alkaloid content of roots was higher in plants treated with poultry manure + panchagavya, which proved to be highly efficient and superior in enhancing plant growth and yield [29].

Effect on growth and yield components

Date of sowing i.e different types environmental conditions also affects the various growth and yield components of plants. In an experiment, Agarwal *et al.* [21] at Jobner (Rajasthan) found that ashwagandha sown on 20th July recorded significantly higher root length (147.5 cm) and root diameter (8.5 mm) compared to other dates of sowing. The results of an experiment conducted at MPKV, Rahuri on sandy loam soils during *kharif* season on the effect of planting dates on growth and yield of ashwagandha indicated no significant influence on 100-seed weight, dry weight of seedlings, number of primary and secondary branches per plant. However, the number of capsules per plant (154.0) and vigor index (385.81) were significantly higher at 15th July planting of ashwagandha [30].

Effect on yield

Date of sowing effect on yield of plant is very important to study. As in Ashwagandha with five dates of sowing i.e. July 20th, 30th and August 7th, 15th and 23^{ed} with ten treatment combinations of nitrogen and phosphorus it was observed that sowing on 7th August gave significant dry root yield (7.77 q/ha) later showed reduction in dry root yield [5].

A field experiment was conducted at Lucknow to study the effect of planting date on plant survival, tuber development and tuber yield of a two years crop of Belladonna (*Discorea floribunda*) by Singh *et al.* [31]. They reported that planting during January, February and March, using seed tubers dug out on the same day, produced 35-40 per cent of plant survival at harvest, tuber growth of 350-410 mg per plant per day (DW basis) and dry tuber yield of 60-65 q per ha, compared to 25 per cent surviving plants, tuber growth rate of 365-425 mg per plant per day and a tuber yield of 35-42 q per ha when planted during June or July. May planting produced the lowest percentage of plant survival (8.9%) and the lowest tuber yield (9.3 q ha^{-1}).

The influence of time of sowing, variety and their interaction on the yield of ashwagandha was studied on medium black soils at Mandsuar (UP) [5]. It was reported that the crop sown on 7th August gave significantly higher root yield (801 kg ha^{-1}). The crop had sown earlier or later showed reduction in root yield. The variety WS-22 produced more root yield than WS-20. In another study, Farooqui and Sreenivas [27] at Bangalore found that the optimum dates of sowing and harvesting for higher root yield (3 to 5 q ha^{-1}) of ashwagandha were July and January respectively.

Agarwal *et al.* [21] in a study conducted on slightly alkaline soil at Jobner, reported that ashwagandha sown on 20th July with 20 cm x 7.5 cm spacing (6.66 lakh plants ha^{-1}) produced the highest root yield (8.2 q ha^{-1}) and seed yield (2.88 q ha^{-1}) compared to other treatments. In a field experiment conducted on sandy loam soils of MPKVV, Rahuri, it was reported that planting on 15th July recorded significantly higher seed yield (164.79 kg ha^{-1}) and vigour index (385.81) in ashwagandha compared to others.

Economics

Agarwal *et al.* [33] conducted a field experiment on sowing time and spacing at Jobner (Rajasthan) on slightly alkaline soil and reported that sowing ashwagandha on 20th July with 6.66 lakh plants per ha at 20 cm x 7.5 cm spacing recorded the highest gross returns (Rs.72, 228 ha^{-1}), net profit (Rs. 56,098 ha^{-1}) and B: C ratio (3.46) compared to other treatments.

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