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Effect of land configuration, manures and bio-stimulants on crop growth rate of ashwagandha under rainfed conditions

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Abstract

Ashwagandha (*Withania somnifera* L. Dunal) is an important medicinal crop widely cultivated under rainfed conditions for its root biomass and bioactive withanolides. A field experiment was conducted to evaluate the effect of land configuration, manures, and bio-stimulants on crop growth rate (CGR) of ashwagandha under ashwagandha-rice intercropping system during 2023-24 and 2024-25. The treatments included two land configuration (Broad bed and furrow and Ridge and furrow), two manures (Poultry manure and Vermicompost), and four bio-stimulants treatments (Control, Seaweed extract @ 25 kg ha⁻¹, Humic and fulvic acid @ 10 kg ha⁻¹, Seaweed extract @ 12.5 kg ha⁻¹ + humic and fulvic acid @ 5 kg ha⁻¹). Results revealed that CGR was significantly influenced by crop establishment methods at all growth stages. Broad bed and furrow recorded consistently higher CGR compared to ridge and furrow, with maximum values at 90 DAS (15.16 and 15.14 g m⁻² day⁻¹ during 2023-24 and 2024-25, respectively). Among organic manures, poultry manure showed higher CGR than vermicompost at different growth stages. Bio-stimulant application significantly enhanced CGR from 60 DAS onwards, with the combined application of seaweed extract + humic and fulvic acid recording the highest values at 90 DAS (12.24 and 12.10 g m⁻² day⁻¹ in 2023-24 and 2024-25, respectively), while control recorded the lowest CGR throughout the crop growth period. The study concludes that broad bed and furrow system, poultry manure, and integrated bio-stimulant application significantly improve crop growth rate of ashwagandha under rainfed conditions.

Keywords: Ashwagandha, crop growth rate, intercropping, land configuration and poultry manure

Introduction

Ashwagandha (*Withania somnifera* (L.) Dunal), commonly known as Indian ginseng or winter cherry, is one of the most important medicinal plants of the family Solanaceae and occupies a prominent position in the traditional systems of medicine, particularly Ayurveda, due to its diverse therapeutic properties (Kaur *et al.*, 2018) [7]. The roots of ashwagandha are rich in biologically active steroidal lactones, collectively known as withanolides, among which withanolide A and withaferin A are the major pharmacologically important constituents responsible for its adaptogenic, antioxidant, anti-inflammatory, immunomodulatory, neuroprotective and anticancer activities (Kaur *et al.*, 2018; Singh *et al.*, 2024) [7, 14]. Owing to the increasing global demand for herbal medicines, nutraceuticals and phytopharmaceutical products, commercial cultivation of ashwagandha has expanded considerably during the last decade. Consequently, the development of sustainable agronomic practices that enhance growth, yield and quality under resource-constrained environments has become an important research priority (Kulkarni and Dhir, 2008; Kaur *et al.*, 2018) [9, 7].

Ashwagandha is predominantly cultivated under rainfed conditions in the semi-arid and sub-tropical regions of India, where crop productivity is largely governed by rainfall distribution, soil moisture availability and nutrient dynamics. Frequent dry spells, low soil organic matter and poor nutrient use efficiency often restrict vegetative growth, dry matter accumulation and root development, ultimately reducing economic yield (Jat *et al.*, 2021) [6]. Therefore, improving crop

growth through appropriate agronomic interventions is essential for achieving sustainable productivity in rainfed ecologies.

Crop growth rate (CGR) is a key physiological indicator that measures the rate of dry matter accumulation per unit ground area over a specified time interval and reflects the overall efficiency of crop growth and productivity. Crop growth rate integrates the combined effects of canopy development, leaf area expansion, photosynthetic efficiency, assimilate partitioning and nutrient uptake, thereby providing a comprehensive assessment of plant performance under different agronomic management practices (Taiz *et al.*, 2018; Lambers *et al.*, 2021) [15, 10]. In medicinal crops such as ashwagandha, a higher CGR during the vegetative and root development phases enhances biomass production and facilitates greater translocation of photosynthates to the roots, ultimately improving root yield and quality. Agronomic interventions that optimize soil moisture availability, nutrient supply and physiological activity are therefore expected to sustain higher crop growth rates, particularly under rainfed conditions where intermittent moisture stress frequently limits biomass accumulation (Rouphael and Colla, 2020) [13].

Among agronomic interventions, land configuration plays a vital role in improving the soil-water-plant relationship under rainfed agriculture. Appropriate planting methods such as broad bed and furrow (BBF) and ridge and furrow systems improve rainwater infiltration, reduce surface runoff, facilitate excess water drainage during heavy rainfall events and enhance soil aeration within the root zone (Kaur *et al.*, 2017; Jat *et al.*, 2021) [8, 6]. Improved soil moisture storage and favourable root-zone conditions promote root proliferation, nutrient acquisition and photosynthetic activity, resulting in greater dry matter accumulation and enhanced crop growth. Although the beneficial effects of land configuration have been widely demonstrated in cereals and legumes, comparable information for medicinal crops, particularly ashwagandha, remains limited.

Organic manures constitute another important component of sustainable crop production systems. Farmyard manure, vermicompost and poultry manure not only supply essential macro- and micronutrients but also improve soil physical, chemical and biological properties through increased soil organic carbon, microbial activity, aggregate stability and water-holding capacity (Ram *et al.*, 2015; Jat *et al.*, 2021) [12, 6]. Vermicompost contains plant growth-promoting substances such as humic compounds, enzymes and beneficial microorganisms that stimulate root growth and nutrient uptake, whereas poultry manure provides readily available nitrogen, phosphorus and potassium required for vigorous vegetative growth (Atiyeh *et al.*, 2002; Ram *et al.*, 2015) [1, 12]. The improvement in soil fertility and plant nutrition resulting from organic amendments enhances leaf area development, chlorophyll synthesis and photosynthetic efficiency, thereby increasing biomass production and crop growth rate.

In recent years, plant bio-stimulants have emerged as an effective strategy for improving crop performance under abiotic stress conditions. Bio-stimulants such as seaweed extracts, humic and fulvic acids, protein hydrolysates and beneficial microorganisms enhance nutrient uptake, stimulate enzymatic activity, improve chlorophyll biosynthesis and strengthen antioxidant defence mechanisms beyond their nutritional contribution (Calvo *et al.*, 2014; du Jardin, 2015; Bulgari *et al.*, 2015; Rouphael and Colla, 2020) [3, 4, 2, 13]. These compounds also improve water-use efficiency and drought tolerance by regulating physiological and biochemical processes, thereby maintaining higher photosynthetic activity and biomass accumulation under rainfed conditions. Recent studies have demonstrated that the combined

application of organic manures and bio-stimulants improves vegetative growth, dry matter production and root yield of ashwagandha more effectively than their individual application (Giridharan *et al.*, 2025) [5].

Although several studies have independently evaluated the effects of land configuration, organic nutrient management or bio-stimulants on crop growth and yield, information regarding their interactive influence on crop growth rate of ashwagandha under rainfed conditions remains scarce. Furthermore, integrated studies combining moisture-conserving land configurations with organic nutrient sources and bio-stimulants are limited, particularly under the rainfed agro-ecological conditions of the Indo-Gangetic Plains. Understanding the combined effects of these management practices is therefore essential for developing sustainable production technologies capable of improving growth, biomass accumulation and root productivity of ashwagandha under moisture-limited environments. Hence, the present study was undertaken to evaluate the effect of land configuration, organic manures and bio-stimulants on crop growth rate of ashwagandha under rainfed conditions.

Materials and Methods

A field experiment was carried out at the Agricultural Research Farm, Banaras Hindu University, Varanasi during two consecutive years 2023-2024 and 2024-2025. The experimental site is geographically situated at an elevation of 74.4 meters above mean sea level, with precise coordinates of 25°15'17" North latitude and 82°59'27" East longitude, centrally located within the North-Gangatic Alluvial Plain. The experimental site has even topography, well-drained soil conditions, and light to medium textured upland rainfed, which does not experience water stagnation during the rainy season.

The experiment was conducted using a split-plot design. The main plot treatments consisted of combination of two land configurations and two manures. The land configurations included CE₁, Broad bed and furrow and CE₂, Ridge and furrow. These were combined with two manures, M₁, Poultry manure and M₂, Vermicompost, resulting in four main plot treatment combinations (2 land configurations × 2 manures). Each main plot was further subdivided into four sub-plots to which different bio-stimulants treatments were applied: B₀ (Control -No bio-stimulants), B₁ (Seaweed extract granules @ 25 kg ha⁻¹), B₂ (Humic acid+fulvic acid granules @ 10 kg ha⁻¹), and B₃ (Seaweed extract granules @ 12.5 kg ha⁻¹ + humic acid and fulvic acid granules @ 5 kg ha⁻¹). This arrangement produced a total of 16 treatment combinations and 48 experimental units in the experiment.

Crop growth rate (CGR)

$$\text{Crop growth rate (g m}^{-2}\text{day}^{-1}) = \frac{1}{P} \times \frac{W_2 - W_1}{(t_2 - t_1)}$$

Where, P= Ground area upon which dry weight was recorded

W₁ = Total dry matter of crop plant at time interval T₁

W₂ = Total dry matter of crop plant at time interval T₂

The data obtained were statistically analyzed using analysis of variance (ANOVA) for split-plot design as described by Gomez and Gomez (1984). The significance of treatment effects was tested at 5% level of probability, and treatment means were compared using critical difference (CD) wherever applicable.

Results and Discussion

Crop growth rate (CGR) of ashwagandha was significantly

influenced by land configuration, manures, and bio-stimulants at different growth stages during both years (Table 1). Among crop establishment methods, broad bed and furrow (BBF) recorded higher CGR than ridge and furrow at all growth stages. At 90 DAS, BBF recorded CGR of 15.16 and 15.14 g m⁻² day⁻¹, whereas ridge and furrow recorded 7.94 and 7.95 g m⁻² day⁻¹ during 2023-24 and 2024-25, respectively. At harvest, BBF also showed higher CGR (3.90 and 4.05 g m⁻² day⁻¹) compared to ridge and furrow (3.29 and 3.41 g m⁻² day⁻¹). Among organic manures, poultry manure recorded higher CGR than vermicompost at most stages. At 90 DAS, poultry manure recorded CGR of 11.75 and 11.76 g m⁻² day⁻¹, while vermicompost recorded 11.35 and 11.34 g m⁻² day⁻¹ during 2023-24 and 2024-25, respectively. At harvest stage, poultry manure also maintained slightly higher CGR. Regarding bio-stimulants, the combined application of seaweed extract + humic and fulvic acid recorded the highest CGR at all stages from 60 DAS onwards. At 90 DAS, this treatment recorded CGR of 12.24 and 12.10 g m⁻² day⁻¹, followed by humic + fulvic acid alone and seaweed extract alone. Control recorded the lowest CGR throughout. At 30 DAS, differences among bio-stimulant treatments were non-significant.

The higher crop growth rate under broad bed and furrow (BBF) system can be attributed to improved soil physical conditions, better moisture conservation, and efficient drainage under rainfed environments. BBF helps in reducing runoff losses and maintaining optimum root-zone moisture, which enhances root proliferation and nutrient uptake, resulting in higher biomass accumulation. Similar findings have been reported by Kaur *et al.* (2017) [8] and Jat *et al.* (2021) [6], who observed improved crop growth and productivity under BBF systems in rainfed agro-

ecosystems. In addition, in the present study ashwagandha was grown as an intercrop with rice, and this system may have influenced resource utilization, particularly light interception, soil moisture dynamics, and nutrient sharing, which could also have contributed to variations in CGR between establishment methods. Among organic manures, higher CGR under poultry manure application may be due to its faster mineralization rate and higher availability of readily accessible nutrients, especially nitrogen, which promotes rapid vegetative growth and leaf area expansion. Vermicompost, although comparatively slower in nutrient release, improves soil structure, microbial activity, and long-term nutrient availability. The positive effect of organic manures on crop growth parameters of ashwagandha has also been reported by Ram *et al.* (2015) [12] and Jat *et al.* (2021) [6], who emphasized improved biomass production and physiological efficiency under organic nutrient management systems. The significant improvement in CGR with biostimulant application, particularly the combined use of seaweed extract and humic + fulvic acid, can be attributed to enhanced physiological and biochemical processes in plants. Seaweed extracts contain natural growth-promoting substances such as auxins, cytokinins, and betaines, which stimulate cell division, chlorophyll formation, and root development. Humic substances improve nutrient uptake efficiency and membrane permeability, thereby enhancing photosynthetic activity and biomass production. These findings are in agreement with Calvo *et al.* (2014) [3], du Jardin (2015) [4], and Rouphael and Colla (2020) [13], who reported that bio-stimulants improve plant growth and stress tolerance by modulating physiological processes beyond simple nutrition.

Table 1: Effect of treatments on crop growth rate (CGR) of ashwagandha at various growth stages

Treatments	CGR (g m ⁻² day ⁻¹)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
Crop establishment methods (a)								
Broad bed and furrow (3:1)	0.49	0.52	2.94	3.00	15.16	15.14	3.90	4.05
Ridge and furrow (1:1)	0.34	0.35	1.16	1.19	7.94	7.95	3.29	3.41
SEm±	0.03	0.03	0.07	0.07	0.12	0.13	0.10	0.12
CD (p=0.05)	0.10	0.09	0.25	0.23	0.39	0.41	0.32	0.40
Organic manures (b)								
Poultry manure (20 kg ha ⁻¹ N)	0.47	0.50	2.19	2.24	11.75	11.76	3.89	3.99
Vermicompost (20 kg ha ⁻¹ N)	0.36	0.37	1.91	1.95	11.35	11.34	3.30	3.48
SEm±	0.03	0.03	0.07	0.07	0.12	0.13	0.10	0.12
CD (p=0.05)	0.10	0.09	0.25	0.23	0.39	0.41	0.32	0.40
Bio-stimulants (c)								
Control	0.40	0.41	1.92	1.95	10.94	11.02	3.40	3.47
Seaweed extract granules (25 kg ha ⁻¹)	0.41	0.43	2.04	2.05	11.51	11.52	3.58	3.70
Humic acid and fulvic acid granules (10 kg ha ⁻¹)	0.42	0.44	2.05	2.06	11.51	11.54	3.59	3.78
Seaweed extract granules (12.5 kg ha ⁻¹)+Humic acid and fulvic acid granules (5 kg ha ⁻¹)	0.43	0.44	2.18	2.33	12.24	12.10	3.81	3.98
SEm±	0.02	0.02	0.06	0.05	0.10	0.11	0.05	0.06
CD (p=0.05)	NS	NS	0.19	0.16	0.29	0.30	0.16	0.17

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