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RESEARCH ARTICLE

FUNCTIONAL PARTITIONING IN EARLY SOWN *WITHANIA SOMNIFERA* DUNAL. LINN. ATTACKED BY *HADDA* BEETLE

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Abstract: Ashwagandha (*Withania somnifera Dunal. Linn.*); a root medicinal plant is also known with other names like Indian ginseng, Queen of Ayurveda, Winter cherry and Ajagandha. It is distributed inthe major area in the central-western provinces of India. It is containing withaferin-A, 12-deoxywithastramonolide. and withanolide A as the major bioactive compounds with pharmacological importance.*Hadda* beetles (*Henosepilachna vigintioctopunctata*); a polyphagous pest is reported to attack this plant however, there is no information available on the impact of the said pest on growth, development and yield of ashwagandha due to *hadda* beetle attack. In an early (June) sown ashwagandha crop, the attack of the *hadda* beetle caused severe defoliation in August and September. The intensity of the defoliation was so high that almost 95% of the leaves were defoliated. This has resulted in an altered biomass accumulation pattern causing the leaf mass fraction to decline from 0.184 in August to 0.041 in September. This was not a true representation of functional partitioning as photosynthates were already invested in leaves which were being eaten up by the pest. Further, a true recording of biomass allocation could not be done in a condition when biomass data of a leaf became unavailable due to severe defoliation caused by the attack of *hadda*beetles in ashwagandha.

Keywords: Ashwagandha, Biomass allocation, Defoliation, *Henosepilachna vigintioctopunctata*, Leaf mass fraction

INTRODUCTION

Ashwagandha (*Withania somnifera Dunal*. Linn.), a root medicinal crop falls under *rasayana* category according to ayurveda. By providing defence against disease, slowing down the process of ageing and revitalising the body in debilitated conditions, it has a role in promoting health and longevity. Its ayurvedic uses include calming the mind, overcoming weakness and relieving nervous exhaustion. Irrespective of sex, it is reported beneficial across all age groups and even during pregnancy causing no side effects (Sharma et al., 2018).The presence of withanolides in the roots of these crops makes them pharmacologically effective to exhibit antibacterial, antifungal and antitumor properties(Saleem *et al*., 2020). Neurodegenerative diseases,for example, Parkinson's, Huntington's and Alzheimer's diseasescan be managed through the use of ashwagandha (Singh, 2011). Withaferin-A (WA), 12-deoxywithastramonolide (WO) and withanolide A (WD) are the major bioactive compounds found in different plant parts of *W. somnifera*. For being a part of more than 100 formulations for health perspectives, this crop has a significant industrial demand.Widely distributed inthe major area in the central-western provinces of India, it passes through various phenological stages which affect the morphology and quality of the roots(Kalariya *et al*., 2020).

Hadda beetles (*Henosepilachna vigintioctopunctata*); are a polyphagous pest that feed predominantly on eggplant, cucurbits, brinjal, potato and kidney bean. Some *Solanacean* plants, for example, S. *nigrum, S. xanthocarpum, S. torvum, Datura* sp., *Physalis sp* and also *Withaniasomnifera* (L.). are known to host the *hadda* beetles. This pest is distributed from East Asia to South Asia and Australia. Variations in *hadda* beetle prevalence are governed by environmental conditions that differ from agro-climatic conditions and vary from place to place and from year to year (Konar and Mohasin, 2002). For example, in India, the *hadda* beetle was active from the last week of September to mid of December with a peak population of grubs (7.8 nos/plant) and adults (1.73 nos/plant) in 2nd week of October (41 SMW) during two consecutive years of observation at Anand, Gujarat, (N 22° 55', E 072° 66') in

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Ashwagandha crop which was sown during the second fortnight of August 2008 and 2009 (Chaudhary Vipin And Saravanan L, 2011). Another study on the outbreaks of *hadda* beetle on ashwagandha reported pest density at the peak in mid-August which declined in the last week of August reaching zero level in October (Venkatesh, 2006) in the year 2004-05 in Bangalore city. Thus, a few reports containing region-specific information on the prevalence of *hadda* beetle on ashwagandha is available. However, the is no information on the impact of the said pest on the growth, development and yield of the host plant after the attack of the *hadda* beetle and therefore, the study was undertaken.

MATERIALS AND METHODS

Field experiment

A field experiment was conducted for two consecutive in the years 2019 and 2020atthe experimental field of the Directorate of Medicinal and Aromatic Plants Research (DMAPR), Boriavi, Anand, Gujarat, India. This field is geographically located on N 22° 55', E 072° 66', MSL – 45m. The average rainfall is 800 mm and the maximum and minimum temperatures are 42°C and 12.7°C, respectively. Healthy seeds of *W. somnifera* Dunal cultivar JA 134 were sown in the line-to-line spacing of 30 cm and plant-to-plant distance of 20 cm in the first week of June (23rd standard week) in each year. The crop was raised following all recommended agronomic practices like weeding, inter culturing, irrigation and fertilizer application. The presence or absence of larvae and/or adults of *hadda* beetle on the third and fourth pairs of distal leaves on the main branch in randomly selected six plants in one plot was recorded in first week of September. Mean of eight plots was considered to arrive at mean incidence in percentage. The observations on various growth parameters were recorded during the last week of August (2 months and 20 days after sowing) and the last week of September (3 months and 20 days after sowing) in each year.

Measurement of growth parameters

Seven randomly selected plants at both the growth stage were uprooted and plant height, root length and leaf area were measured. The shade-dried weight of the leaves (LDW), stem (SDW), roots (RDW) and berries (BDW) were recorded after proper drying until constant moisture content. From the values of the dry weight of various plant parts, biomass fractions namely leaf mass fraction (LMF), shoot mass fraction (SMF), root mass fraction (RMF) and berry mass fraction (BMF) were calculated as described by Kalariya et al. 2020.

Data analysis and presentation

The data from both the stages of observation (the last week of the August and last week of September) were subjected to analysis of variance for the randomized block design. The DSAASTAT Onofri (2007) in MS Excel-based add-in module was used for statistical analysis and the least significant differences were calculated to assess the significance of treatment means where the "F" test was found significant at $P < 0.05$.

RESULTS AND DISCUSSION

Weather conditions during crop seasons (23-39 Standard week)

Weather parameters during the crop year 2019 and 2020 are presented in figure 1 a-c. During the crop growth period, evaporative demand decreased. It was 9.6 mm and 6.9 mm at the sowing time in the year 2019 and 2020, respectively. Which decreased to 2.8 and 3.2 during the first week of September (35thstandard week) in the year 2019 and 2020, respectively and remained almost constant till the 39thstandard week? The crop was exposed to 74.9 and 85 total bright sunshine hours (BSS) during till39th standard week in years 2019 and 2020, respectively out of which the crop got more than 43% (32 hours) during the first five weeks of sowing. The maximum temperature was 40.8 and 37.0 ^{0}C during sowing time (23rd standard week) inthe year 2019 and 2020 respectively. The average maximum temperature from the first week of June to the last week of September was 33.4 and 34.0 ^{0}C in the year 2019 and 2020 respectively whereas the average minimum temperature during the same period was 25.8 and 26.3 ^{0}C

Pest incidence and plant growth characteristics

The observation on pest incidence revealed the presence of larvae and or adult on more than 95% of the distal leaves on the main branch during first week of September (data not presented). Images of adult, egg mass underneath leaf surface, grub, a typical leaf-eating pattern causing skeletonization of the leaf and a severe defoliated field are presented in figure 2. The data on growth parameters at two months and 80 DAS and 120 DAS are given in table 1. The mean plant height and root length were 18.9 cm and 8.6 cm, respectively at stage I which increased to

30.3 cm and 12.8 cm at stage II respectively. Though the plant height and root length increased with the advancement of the growth stage, the leaf area declined from 176 cm^2 at stage I to 58 cm^2 at stage II. The dry leaf weight (DLW) and dry stem weight (DSW) was 0.96 g $plant^{-1}$ and 3.4 g $plant^{-1}$, respectively at stage I. The DLW decreased to 0.32 g $plant^{-1}$ and the DSW increased to 5.3 g $plant^{-1}$ at stage II. The dry root weight (DRW) was 0.86 g $plant^{-1}$ whereas there was no berry mass formed at stage I. at stage II, the DRW was 1.46 g $plant^{-1}$ and the dry berry weight (DBW) was 0.77 g $plant^{-1}$. The total biomass was 5.24 g $plant^{-1}$ and 7.9 g $plant^{-1}$ at stage I and stage II, respectively.

Functional Partitioning

With the progression of the growth stage, organ-specific biomass accumulation patterns changed in the usual manner except for LMF (table 2). The LMF which was 0.184 at stage I decreased to 0.041 at stage II. The SMF and RMF increased from 0.65 to 0.68 and 0.165 to 0.186, respectively from stage I to stage II. The berry mass fraction (BMF) which was nil at stage I gained 0.097 fractions at stage II. The overall change in biomass fractions was affected by the defoliation of the leaf. The usual sowing time of the Ashwagandha crop in this agro-climatic condition is the 2nd to 3rd week of August. However, an early sown (first week of June) crop of ashwagandha at the Research Field, ICAR-DMAPR, Anand Gujarat raised with a standard package of practices experienced a regular monsoon of this agro-climatic region. From August to September, severe defoliation of the crop was noticed. Investigation of the reasons behind the defoliation revealed that the crop succumbed to the severe attack of *hadda* beetles. The intensity of the defoliation was so high that almost 95% of the leaves were defoliated. This was because of the typical habit of *hadda*beetles eating leaf lamina only and leaving the veins and the mid-rib of the leaf. The leaf after being eaten up becomes skeletonised and eventually drops.

The adult *hadda*beetles attacking *W. somnifera* has 28 black spots on the forewing (elytra). The lower leaf surfaces are the preferred site of egg laying by an adult in *W. somnifera*. The female lays a spindle-shaped egg in a cluster. The spotted beetle, an important pest of the *Solanaceae* family is also reported to attack Cucurbitaceae(Azam, 1974; Mandal, 1971; Mohansundaram, 1973). Some of the *Solanaceous* host plants possess medicinal values(Mathur, 1964; Mitra, 2002; Venkatesh, 2006) and ashwagandha is the most important medicinal plant belonging to the *Solanaceae* family. This very hardy plant grown as a rain-fed crop has a high value and export potential (Chandranath, 2010) for its uses in ayurvedic recipes to treat various formulations (Sangwan, 2004). A similar high level of *hadda*beetle incidence on different crops was reported from June to October in various parts of India (Ghosh, 2001; Ramzan, 1990).

Table 1. Leaf area plant height, root length, leaf dry weight, stem dry weight, root dry weight and berry dry weight in early sown ashwagandha during August (stage I) and September (stage II)

Character		Leaf Area cm^2		Plant height cm		Root length cm		Dry leaf weight g $plant^{-1}$		Dry stem weight g $plant^{-1}$		Dry root weight g $plant^{-1}$		Dry root berry g $plant^{-1}$	
Stage		I	II	I	II	I	II	I	II	I	II	I	II	I	II
Year	2019	172	57	18.8	30.3	8.5	12.7	0.95	0.32	3.3	5.1	0.83	1.4	0.0	0.60
	2020	181	60	19.0	30.2	8.7	12.9	0.97	0.32	3.5	5.5	0.9	1.53	0.0	0.94
mean		176	58	18.9	30.3	8.6	12.8	0.96	0.32	3.4	5.3	0.86	1.46	0.0	0.77
LSD (0.05)		10.6		1.86		0.7		0.05		0.31		0.14		0.17	

Table 2. Total aerial biomass (TABM), total biomass (TBM), leaf mass fraction (LMF), shoot mass fraction (SMF), root mass fraction (RMF) and berry mass fraction (BMF) in early sown ashwagandha during August (stage I) and September (stage II)

Character		TABM g plant^{-1}		TBM g plant^{-1}		LMF		SMF		RMF		BMF	
Stage		I	II	I	II	I	II	I	II	I	II	I	II
Year	2019	4.25	6.06	5.08	7.46	0.188	0.043	0.65	0.69	0.163	0.187	0.000	0.078
	2020	4.49	6.80	5.39	8.33	0.179	0.039	0.65	0.67	0.167	0.185	0.000	0.111
mean		4.37	6.43	5.24	7.90	0.184	0.041	0.65	0.68	0.165	0.186	0.000	0.094
LSD (0.05)		0.45		0.55		0.005		0.016		0.011		0.015	

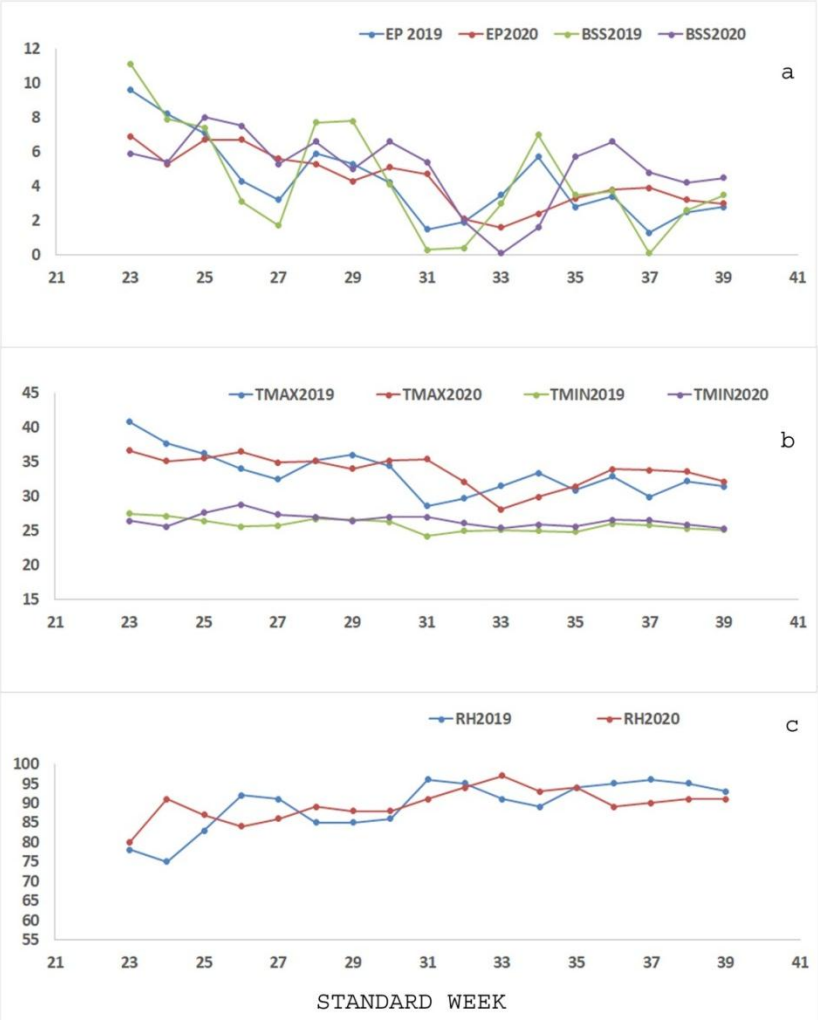

Figure 1. Weather parameters during ashwagandha crop growth period

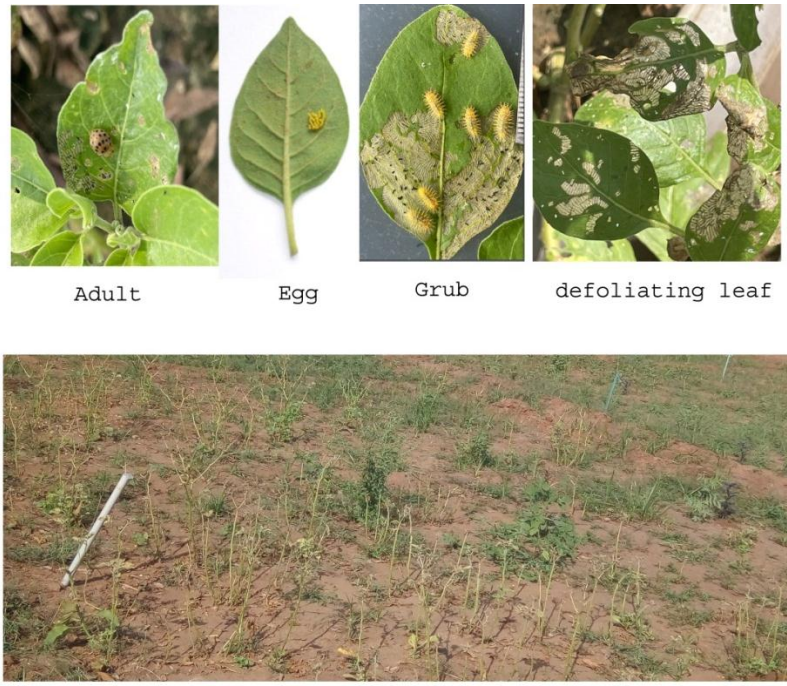

Figure 2. Adult, egg mass underneath leaf surface, grub, a typical leaf eating pattern of *hadda* beetle in ashwagandha during last week of September

The biomass allocation in plants is not constant. It keeps on changing in response to crop growth stage, environmental conditions and species differentiation (Reich P, 2002). Such changes occur due to preferring one or another specific organ to invest the photosynthesis. Therefore, any increase in the relative biomass of any organ competitively inhibits the investment of photosynthesis in one or other organs. However, in this case of a severe attack of *hadda* beetle, the LMF became negligible due to the defoliation of leaves. This was not a true representation of functional partitioning as photosynthates were already invested in leaves which were being eaten up by the pest. Understanding the functional partitioning in a medicinal plant becomes even more complex as in a medicinal plant, the yield of an active principal compound is decided by its quantitative allocation in a specific plant organ and the biomass allocation of such an organ itself is subjected to change due to outside conditions. Further, a true recording of biomass allocation cannot be done in a condition when biomass data of a specific organ becomes unavailable due to severe defoliation caused by a severe attack of *hadda* beetles in ashwagandha.

Declarations

Availability of data and material

All the data generated or analysed during this study were included within the article

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Authors' contributions

KK:Conceptualization, Methodology, Data curation, Writing- Original draft preparation, Writing-Reviewing and Editing, PL: acquisition of data, analysis and interpretation of data, RP: acquisition of data, analysis and interpretation of data, Reviewing and Editing

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