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Variability in *Striga hermonthica* (Del.) Benth, Populations in Gadarif Area, Eastern Sudan

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ABSTRACT

Field surveys were conducted during the rainy season, 2008/2009, in Gadarif area, Eastern Sudan, to investigate variability within *S. hermonthica* populations. Five locations; Galabat, Sumsum, Gadarif, Butana and El Fau were selected at random in *S. hermonthica* endemic area. Variability among *S. hermonthica* populations was determined by measuring morphological and floral characters. Data on *S. hermonthica* morphology were collected and subjected to descriptive analysis and analysis of variance. Means were separated for significance using Duncan's Multiple Range Test (at $p \leq 0.5$). Data on floral characters were subjected to descriptive analysis and compared with the taxonomic key. The results of the surveys revealed that, *S. hermonthica* was pre-dominant on sorghum genotypesin Gadarif area. *S. hermonthica* populations showed significant differences in morphological characters. However, differences in flower shape, size and colour were often not significant.Average *Striga* height ranged between 49.7and76.6 cm, leaves production ranged between 42.4 and 81.7, number of internodes ranged between 21.3 and 41.4 and density ranged between 17.4 and 33.8 plant/m^2.Average of capsules per plant ranged between 42.2 and 109.5, seeds per parasite ranged between 29516.5 and 76626.7 and *Striga* shoot dry weight ranged between 1.01 and 9.02 g.The average of ribs per calyx ranged between 5.3 and 5.7, flower cross ranged between 1.8 and 2 cm, length of corolla tube ranged between 1.7 and 1.9 cm, width of bracts ranged between 2.2 and 2.5 cm and spikes had pink flowers that turn dark at drying. The variability in morphological and floral characters revealed by this study could be attributed to a multitude of variables including initial size of *Striga* seed bank, *Striga* species, strains or variants, crop genotype, management and climatic and edaphic condition including, spacing, soil fertility and moisture status.

Keywords: Witchweed, survey, morphology, flower, taxonomy.

Introduction

Witchweeds (*Striga* spp.), member of the family Orobanchaceae, are obligate root parasitic plants that attack agronomically important cereals and legumes (Anonymous, 1993). *Striga* is the major biotic constraint to cereals production, especially in the non-fertile semi-arid region of Sub-Saharan Africa (Haussmann *et al*., 2000). The parasitenegatively affects the lives of over 300 million people (Kim *et al*., 2002). In extreme cases, severe infestation of *Striga* results in complete loss of the crop and the abandonment of otherwise productive fields (Butler, 1995).

Musselman and Hepper (1986) believed, on basis of common occurrence on wild grasses, that *S. hermonthica* has Sudan as centre of origin. The parasite constitutes a major threat to sorghum (*Sorghum bicolor* [L.] Moench) production and hence a direct threat to food security as sorghum constitutes the main staple food crop for the majority of the Sudanese people in rural areas (Zahran, 2008). The impact of *Striga* is compounded further by its predilection for attacking crops already under moisture and nutrient stress, conditions that prevail throughout the semi-arid tropics (Ejeta and Butler, 1993).

Wilson-Jones (1955) reported two strains of *S. hermonthica* from the Sudan, one specific to sorghum and the other to millet. Sorghum was usually heavily attacked by *S. hermonthica* on the Central clay plains whereas millet was particularly immune, but the reverse is true on the sandy soils of Western Sudan. The existence of intercrop-specific strains in *Striga* has been suggested to be based almost entirely on differential response of variants of the species to root exudates from host cultivars (Bebawi and Farah, 1981).

Understanding the relationship between variability within and among geographically separated populations and host preference should improve the ability to successfully breed for broad and durable resistance to *Striga* species among the most common hosts; sorghum and millet (Christopher *et al.*, 2002). Therefore, this study covers different locations in Gadarif area, Eastern Sudan, with the objective of study variability within *S. hermonthica* populations with respect to morphological characters.

Materials and Methods

Field surveys

Field surveys were conducted during the rainy season 2008/2009 in Gadarif area, Eastern Sudan, to study variability within *S. hermonthica* populations with respect to morphological characters. Five locations were selected randomly, i.e. Galabat, Sumsum, Gadarif, Butana and El Fau. Three sites were selected at random in each location. Three *Striga* infested fields were chosen at random in each site. At time of harvest, ten plots (10X10 m) were selected in each field. Ten quadrates (1 m^2 each) were placed at random in each plot. In each quadrate, variability among *S. hermonthica* was determined by measuring morphological characters including number of plants / m^2, plant height (cm), number of leaves, number of internodes, capsules per plant and shoot dry weight (g). Flower characters including number of ribs per calyx, flower width (cm), Length of corolla tube (cm), bracts width (cm), colour of spike and colour at drying were also observed and determined.

Statistical analysis

Data on *S. hermonthica* morphology were subjected to descriptive analysis and analysis of variance (ANOVA). Where the test was significant, separation of means was done using Duncan's Multiple Range Test ($P \leq 0.05$). Data on flower characters were subjected to descriptive analysis and

compared with the taxonomic key published by Parker and Riches, (1993).

Results

Field surveys

Host plant species and cultivars that were observed to be infested by *S. hermonthica* in the endemic areas in Eastern Sudan during the rainy season, were; sorghum genotypes: Wad Ahmed, Fetarita, Adar, Korakolo, Arfaa Gadamk, Agab Seido, Zahrat Gadambalia and Local sorghum; and millet genotype:White millet (Table 1).

Variability within *S. hermonthica* populations

Variability within *S. hermonthica* populations was studied with respect to general morphological and flower characters.

General *S. hermonthica* morphology

Irrespective of host plants, there were significant differences in *S. hermonthica* growth parameters; number of plants per m^2, plant height, number of leaves, number of internodes and harvest parameters including capsules per plant, seeds per plant and shoot dry weight within and between locations.

At Galabat location, the number of *Striga* plants per m^2 was 32, 24 and 25 on Korakolo, Wad Ahmed site I and site II, respectively (Fig. 1A). The corresponding average height of *S. hermonthica* was 94, 54 and 82 cm, respectively. On the other hand, the average number of *S. hermonthica* leaves and internodes was 86 and 42 on Korakolo, 69 and 34 on Wad Ahmed (site I), 61 and 30 on Wad Ahmed site II, respectively. The average number of capsules per *S. hermonthica* plant was 93 on Korakolo, 87 on Wad Ahmed (site I) and 66 on Wad Ahmed site II (Fig. 1B). The average shoot dry weight of *S. hermonthica* was 8.8 g on Korakolo, 9.5 g on Wad Ahmed site I and 8.8 g on Wad Ahmed site II (Fig. 1B).

At Sumsum location, the number of *Striga* plants per m^2 was 19 on Local sorghum, 6.1 on White millet and 27 on Adar (Fig. 2A). The average height of *S. hermonthica* was 45, 43 and 61cm on local sorghum, white millet and Adar, respectively. Moreover, the average number of *S. hermonthica* leaves was 70 on Local sorghum, 59 on White millet and 70 on Adar. The corresponding average number of internodes was 37 on Local sorghum, 30 on White millet and 35 on Adar, respectively. The average number of capsules per *S. hermonthica* plant was 51 on Local sorghum, 53 on White millet and 58 on Adar (Fig. 2B).The average shoot dry weight of *S. hermonthica* was 2.3, 1.3 and 6.3 g on Local sorghum, White millet and Adar, respectively.

At Gadarif location, the number of *Striga* plants per m^2 was 62, 36 and 3.1 on Arfaa Gadamk, Agab Seido and White millet, respectively (Fig. 3A). The corresponding average height of *S. hermonthica* was 56, 75 and 40 cm, respectively. Furthermore, the average number of leaves and internodes was 90 and 45 on Arfaa Gadamk, 94 and 48 on Agab Seido, 61 and 36 on White millet, respectively. The average of capsules per *S. hermonthica* plant was 101 on Arfaa Gadamk, 167 on Agab Seido and 61 on White millet (Fig. 3B). The average shoot dry weight of *S. hermonthica* was 6.2 g on Arfaa Gadamk, 7.3 g on Agab Seido and 1.4 g on White millet.

At Butana location, the number of *Striga* plants per m^2 was 4 on Adar, 44 on Zahrat Gadambalia and 19 on Wad Ahmed (Fig. 4A). The average height of *S. hermonthica* was 86, 37 and 49 cm on Adar, Zahrat Gadambalia and Wad Ahmed, respectively. On the other hand, the average number of leaves was 48 on Adar, 24 on Zahrat Gadambalia and 56 on Wad Ahmed. The average number of internodes was 23 on Adar, 13 on Zahrat Gadambalia and 21 on Wad Ahmed, respectively. The average of capsules per *S. hermonthica* plant was 44 on Adar, 18 on Zahrat Gadambalia and 65 on

Wad Ahmed (Fig. 4B). The average shoot dry weight of *S. hermonthica* plantwas 1.4, 0.4 and 1.3 g on Adar, Zahrat Gadambalia and Wad Ahmed, respectively.

At El Fau location, the number of *Striga* plants per m^2 was 17, 22 and 24 on Fetarita (site I), Fetarita (site II) and Wad Ahmed, respectively (Fig. 5A). The corresponding average height of *S. hermonthica* was 50, 61 and 66 cm, respectively. Moreover, the average number of *S. hermonthica* leaves and internodes was 45 and 22 on Fetarita site I, 57 and 30 on Fetarita (site II), 59 and 30 on Wad Ahmed, respectively. The average of capsules per *S. hermonthica* plant was 50 on Fetarita (site I), 59 on Fetarita site II and 68 on Wad Ahmed (Fig. 5B). The average shoot dry weight of *S. hermonthica* was 1.6 g on each of Fetarita site I, site II and Wad Ahmed.

Description of *S. hermonthica* flower

S. hermonthica populations collected from different locations in Gadarif area, Eastern Sudan, showed variations in diagnostic features of flower (Table 2). The average number of ribs on the calyx ranged between 5.3 for populations collected from Butana and El Fau to 5.7 for population collected from Galabat (Table 2). The average flower width ranged between 1.8 cm for populations collected from Butana and El Fau to 2 cm for population collected from Gadarif. The average corolla tube length was 1.7 cm for populations collected from Butana and El Fau to 1.9 cm for populations collected from Galabat. The average bracts width ranged between 2.2 mm for population collected from Galabat and Sumsum to 2.5 mm for population collected from Gadarif and El Fau. Spikes had pink flowers that turned dark after senescence (Table 2).

Discussion

The results of the field surveys during the rainy season revealed that, all sorghum genotypes in*Striga* endemic area were observed to be infested by the parasite (Table 1). However, *Striga* infestation in millet was observed only in Gadarif and Sumsum locations (Table 1). Wilson-Jones (1955) observed that, two strains of *S. hermonthica* exist in Sudan. One prevailing in Eastern and central Sudan and attacked sorghum but not millet. While in western Sudan, both millet and sorghum were attacked.

In Eastern Sudan, sorghum predominates but millet is rarely grown. However, in eastern Sudan both crops are cultivated often in the same field. Furthermore, *Striga* is known to adapt itself to cropping system. Differences in host plant adaptation among populations of *Striga* have been reported (Ejeta *et al.* 1993). Introduction of maize into sorghum based cropping system, initially decreases *Striga* seed population density in soil, but the effect does not last and heavy infestation of the crop often develops. This phenomenon is most likely due to changes in genetic composition of *Striga* population. The frequent cropping of maize results in selection and gradual build-up of races which are phonologically and physiologically adapted to the crop. Analysis of this apparent contradictory phenomenon may offer better understanding of adaptation (host specificity) and adaptability (exceptions to host specificity) of *Striga*. A similar observation was made in Ethiopia where teff (*Eragrostistef* (Zuccagni) Trotter) previously considered immune to *S. hermonthica* was reported to be attacked (Parker and Riches, 1993).

The results of the field surveys also revealed significant variability within *S. hermonthica* populations with respect to general morphological and floral characters (Fig. 1–5 and Table 2). This finding is in line with previous reports in existence of morphot-ypes in *Striga* (Ejeta *et al.*, 1993). *S. hermonthica* height was 59.9 cm in Gadarif

area. However, plant height, across the surveyed location ranged between 49.7 and 76.6 cm (Table 3). The average number of leaves produced by *S. hermonthica* plant was 63.2, while the number of leaves ranged between 42.4 and 81.7 across the location surveyed (Table 3). The average number of internodes was 31.9 in Eastern Sudan. However, number of internodes ranged between 21.3 and 41.4 (Table 3). The variability in morphological and floral characters was in line with those reported by Andrews (1945) who found that, *S. hermonthica* has bright to dark green leaves, erect and usually branched stems grow up to 60 cm or more. Stems are stout and quadrangular. Leaves are linear, lanceolate or lanceolate with acuate or acuminate tips, 1-3 in. long, very scabrous. Furthermore, results support the existence of morphotypes.

The results showed that, the average production of capsules per *S. hermonthica* plant was 69.2 in Gadarif area (Table 4), while, the total number of capsules per plant was 42.2 and 109.5 across surveyed locations (Table 4). A previous report by Parker and Riches (1993) showed that, the number of capsules per plant may be about 14 in *S. forbesii*, but ranged between 60 and 70 in *S. hermonthica* and *S. asiatica*. The average number of seeds produced per *S. hermonthica* plant was 48454.0 in Gadarif Sudan (Table 4). However, the range across the surveyed area was 29516.5 to 76626.7 (Table 4). This finding is in conformity with that reported by Andrews (1945) who reported that, the number of seeds per capsule is about 700 in *S. hermonthica*.Visser (1981) working with *S. asiatica* showed that one plantis capable of producing up to half a million minute dust like seeds in a single growing season. Parker and Riches (1993) recorded a 7 µg, as an average weight for *Striga* seed. Moreover, they claimed production of 58000 seedsper plant by *S. asiatica*. The results of this study is in line with the reported seed productivity of *S. hermonthica* and suggest that *S. hermonthica* may be less copious seed producer than *S. asiatica*. The average shoot dry weight of S. *hermonthica* was 4.12 g in Gadarif area (Table 4). However, the range in shoot dry weight showed considerable variability and was 1.01-14.0 g. Dafaallah (2006) based on pot experiment reported a dry weight of 1.83g per *S. hermonthica* plant. The low dry weight recorded by Dafaallah (2006) may be due to, among other factors, restriction of growth of both the host and the parasite inflicted by the available resources. *Striga* population density displayed considerable variability both within and between locations. The number of *Striga* plants per m^2 was 26.2 in Gadarif area (Table 3). However, within surveyed locations, the mean density of the parasite ranged between 17.4 and 33.8 plants/m^2. The close association between the *Striga* and its host with and the environment together with copious seed production and ease of destination my maximize the risk of spread of the parasite by the ongoing climate change (Mohamed *et al.*, 2007).

S. hermonthica populations collected from different locations in Gadarif area, showed considerable variations in diagnostic features of the flower (Table 2). Average width of bracts was 1.2–2.5 mm. Average number of ribs on the calyx was 5.3–5.7. Average length of corolla tube was 1.7-1.9 cm. Furthermore, spikes had pink flowers that turn dark on drying. These results are in agreement with those reported by Parker and Riches (1993) who showed that, the inflorescence of *S. hermonthica* possesses 6-10 open flowers that are pink and 1-2 cm across. Calyxribs usually 5 or 6 (1 per calyx lobe). Corolla tube is 1.5-2 cm long, bracts below each flower 2-3 mm wide (Table 2). The variability in morphological and floral characters revealed by this study and

elsewhere (Parker and Riches (1993) could be attributed to a multitude of variables including initial size of *Striga* seed bank, *Striga* species, strains or variants, crop genotype, management and climatic and edaphic conditions including spacing, soil fertility and moisture status (Fig. 1-5 and Table 2).

Conclusions and Suggestions

S. hermonthica in Gadarif area, Eastern Sudan, pre-dominated on sorghum.

- *S. hermonthica* populations collected from different locations in Gadarif area, Eastern Sudan, showed significant differences in morphological characters. However, differences in flower shape, size and colour were often not significant.
- The variability in morphological and floral characters revealed by this study could be attributed to a multitude of variables including initial size of *Striga* seed bank, *Striga* species, strains or variants, crop genotype, management and climatic and edaphic conditions including spacing, soil fertility and moisture status.

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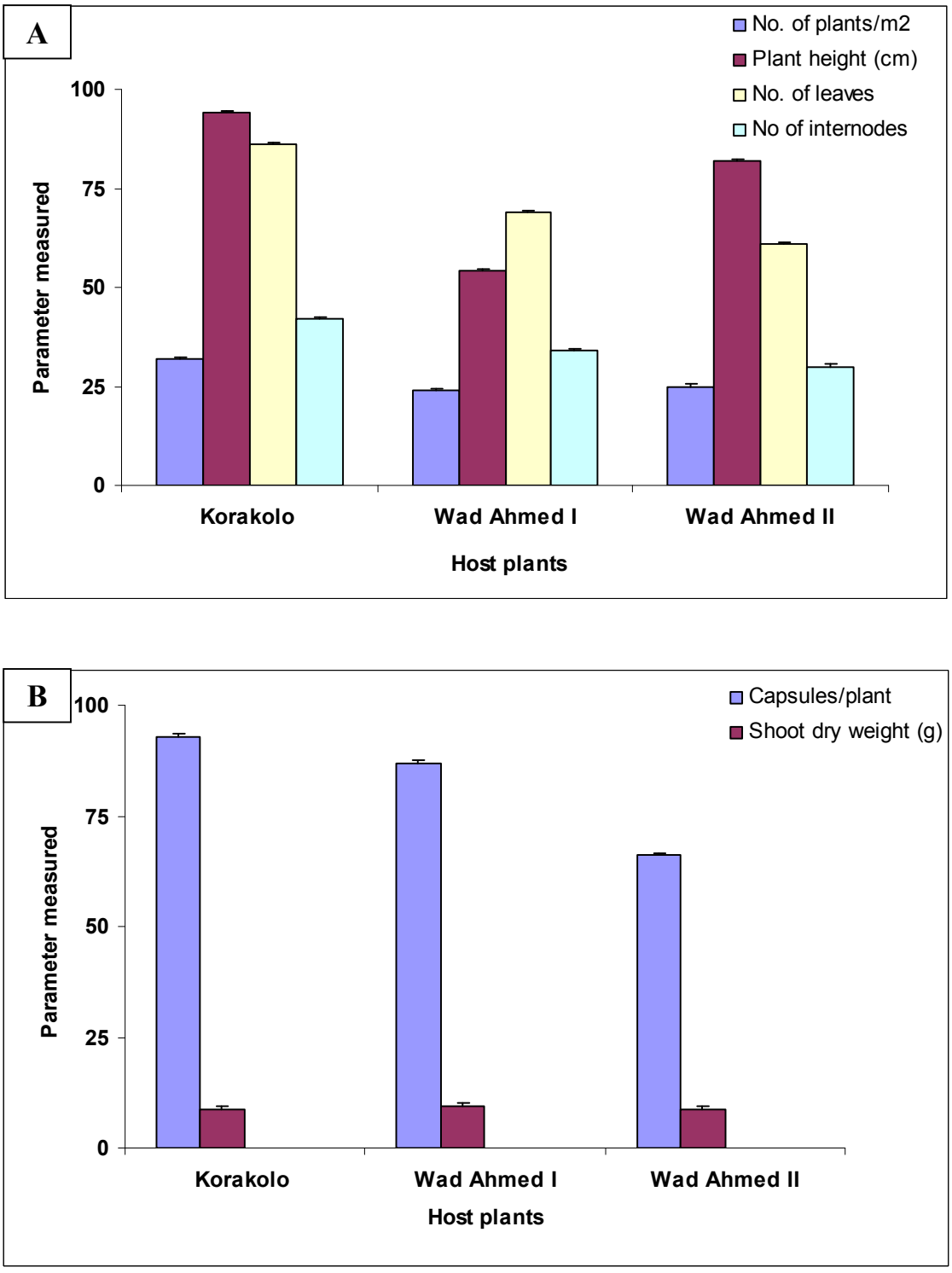


Fig. 1. Means ofselectedgrowth and harvest parameters of *S. hermonthica* at Galabat location. Vertical bar represents ± standard deviation.

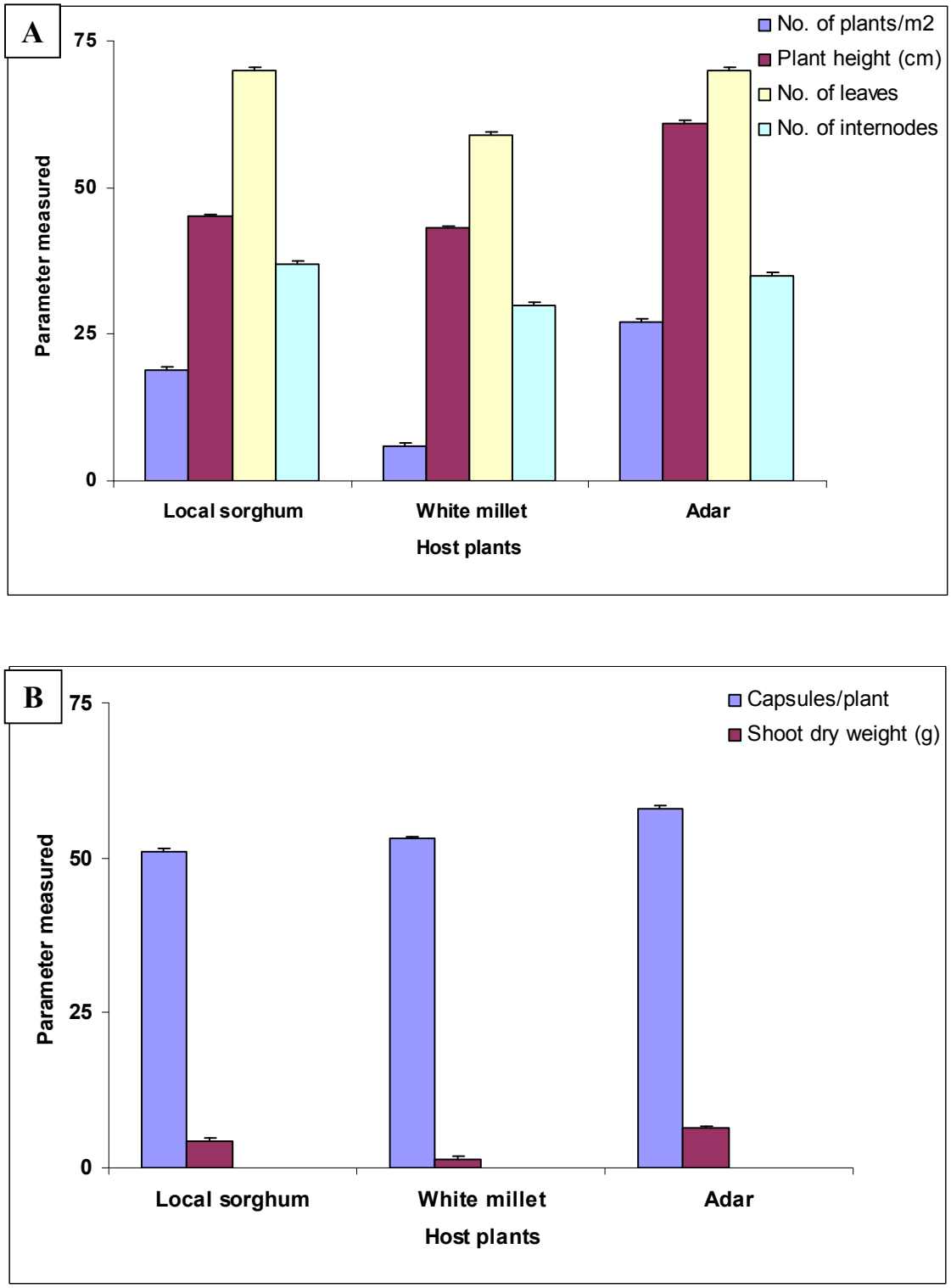
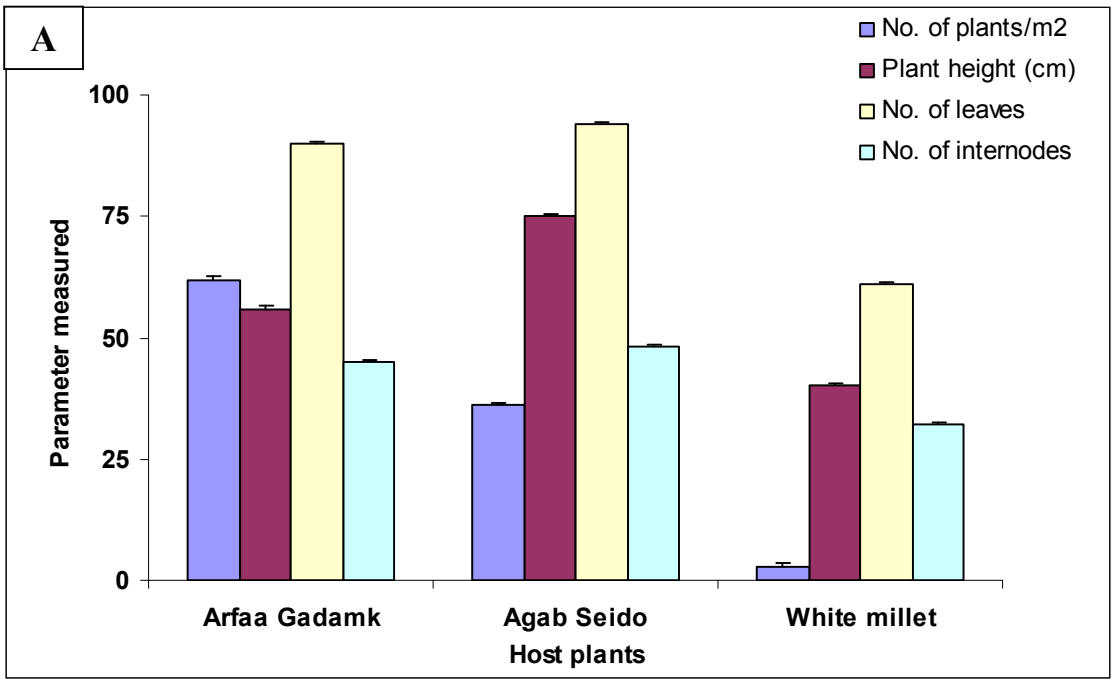


Fig. 2. Means ofselected growth andharvest parameters of *S. hermonthica* at Sumsum location. Vertical bar represents ± standard deviation.



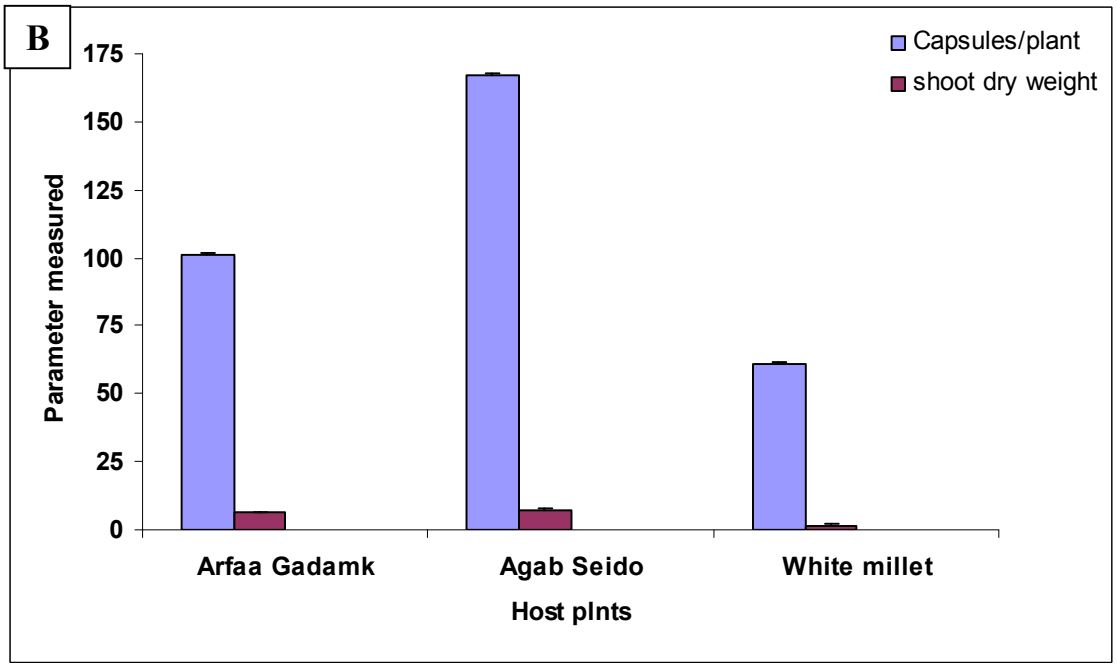


Fig. 3. Means ofselected growth andharvest parameters of *S. hermonthica* at Gadarif location. Vertical bar represents ± standard deviation.

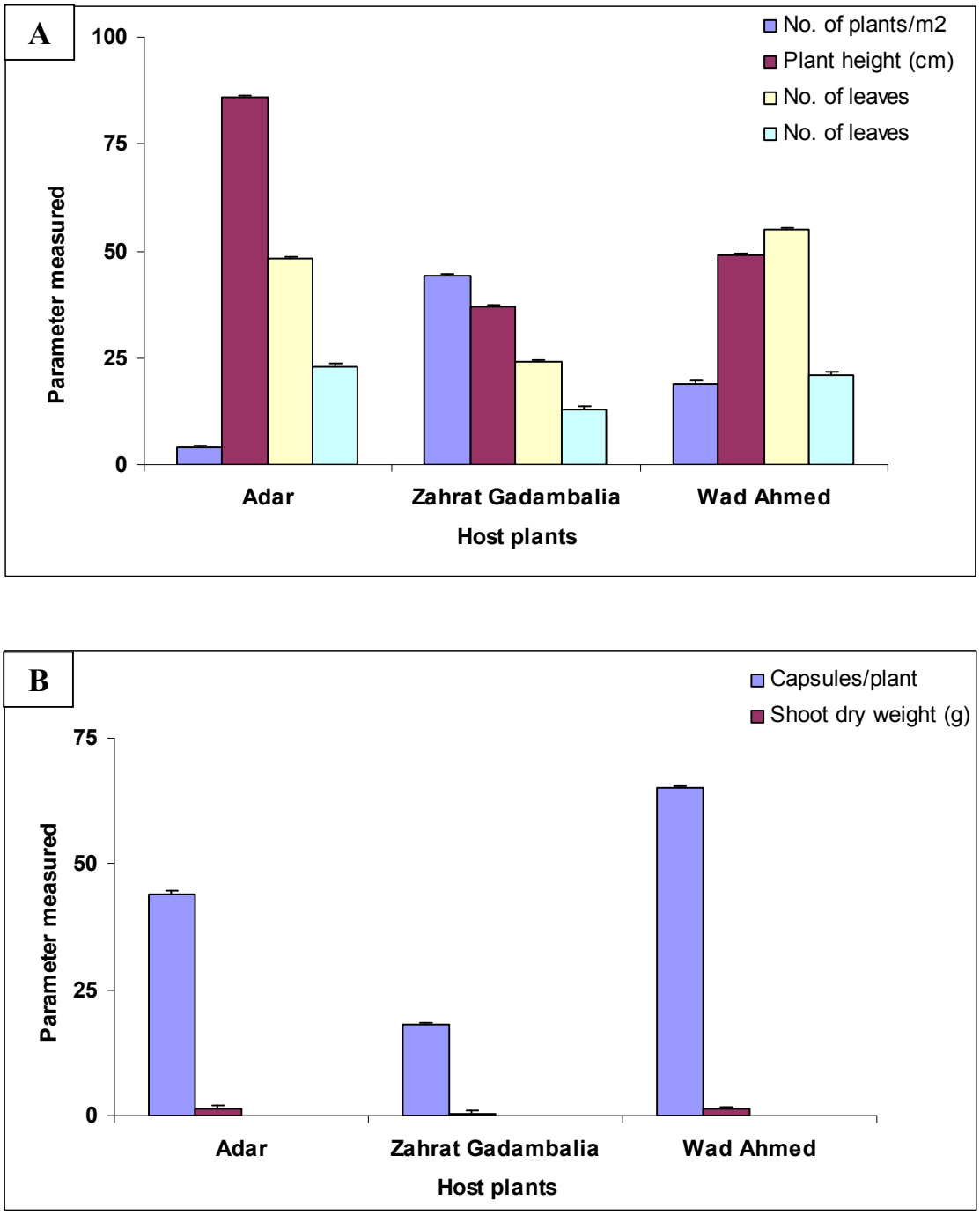


Fig.4. Means ofselected growth andharvest parameters of *S. hermonthica* at Butana location. Vertical bar represents ± standard deviation.

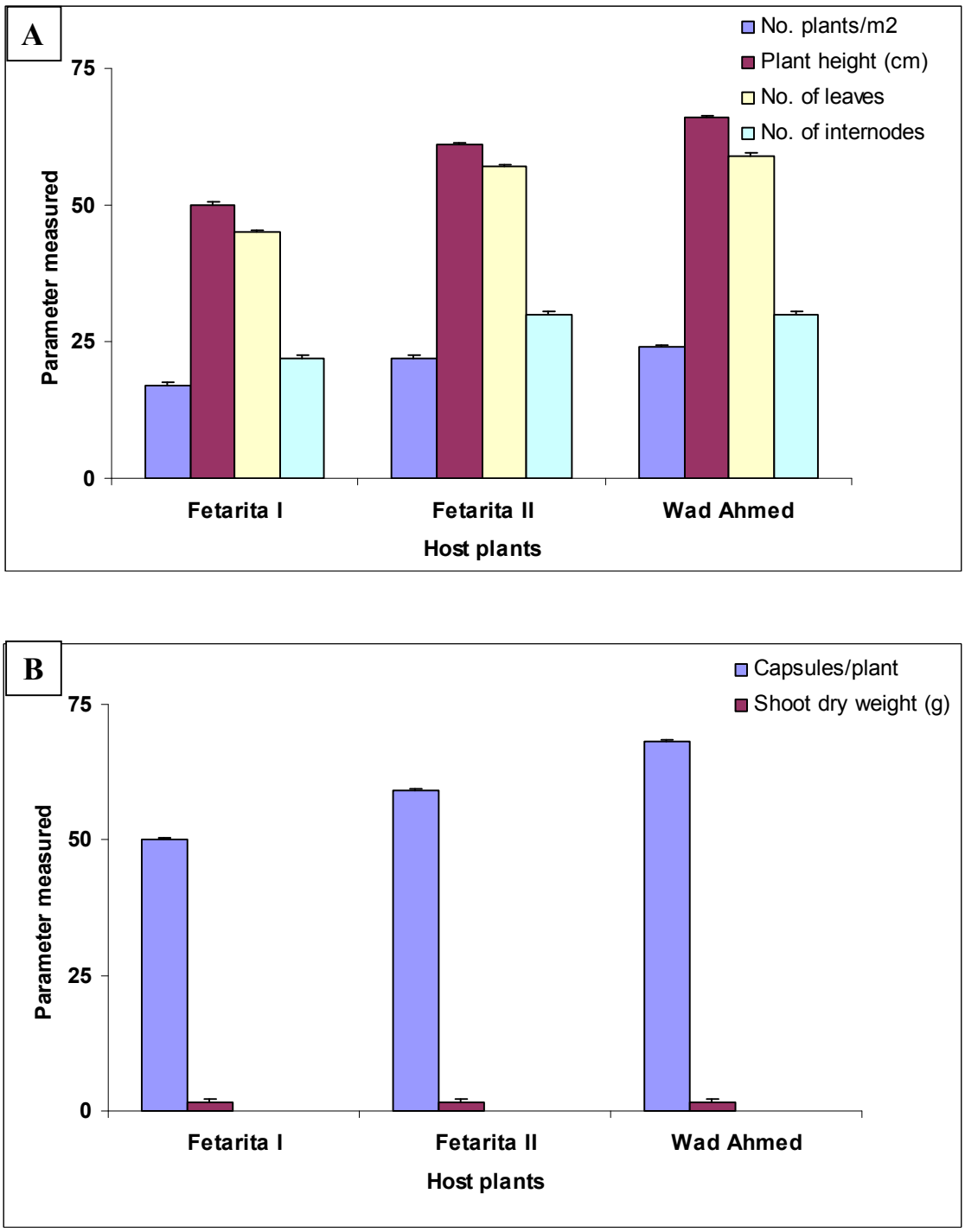


Fig.5. Means ofselected growth andharvest parameters of *S. hermonthica* at El Fau location. Vertical bar represents ± standard deviation.

Table 1: *S. hermonthica* collection sites in Gadarif area, Eastern Sudan, and host plants upon which the parasite was growing

Location	Host plant		
	Sites		
	Site I	Site II	Site III
Galabat	Korakolo*	Wad Ahmed*	Wad Ahmed*
Sumsum	Local*	White**	Adar*
Gadarif	Arfaa Gadamk*	Agab Seido*	White**
Butana	Adar*	ZahratGadambalia*	Wad Ahmed*
El Fau	Fetarita*	Fetarita*	Wad Ahmed*

*, ** = Sorghum and Millet genotypes, respectively.

Table 2:Variability within *S. hermonthica* populations with respect to flower description

Location	Flower characters									
	No. of ribs / calyx		Flower width (cm)		Length of corolla tube (cm)		Bracts width (mm)		Colour of spike	Colour at drying
		±SD		±SD		±SD		±SD		
Galabat	5.7	0.00	1.9	0.03	1.9	0.06	2.2	0.03	Pink	Dark
Sumsum	5.4	0.12	1.9	0.09	1.8	1.44	2.2	0.14		
Gadarif	5.5	0.40	2.0	0.08	1.8	0.05	2.5	0.17		
Butana	5.3	0.12	1.8	0.08	1.7	0.09	2.4	0.06		
El Fau	5.3	0.15	1.8	0.00	1.7	0.13	2.5	0.00		

M, SD = Mean and Standard Deviation, respectively.

Table 3: Means of *Striga* growth parameters in different locations

Locations	*Striga* Growth parameters			
	No. of plants / m^2	Plant height (cm)	No. of leaves	No. of internodes
Galabat	26.8 [b]	76.6 [a]	71.9 [b]	35.5 [b]
Sumsum	17.4 [e]	49.7 [d]	66.3 [c]	33.8 [c]
Gadarif	33.8 [a]	57.0 [c]	81.7 [a]	41.4 [a]
Butana	22.2 [c]	57.1 [c]	42.4 [e]	21.3 [e]
Fau	20.9 [d]	58.9 [b]	53.8 [d]	27.3 [d]
Mean	25.05	59.86	63.22	31.86
SE ±	0.153	0.209	0.200	0.154
CV %	11.0	12.8	9.8	12.8

* Means in the same column followed by the different letter(s) are significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.

Table 4: Means of *Striga* parameters at harvest in different locations

Location	Harvest parameters		
	Capsules/ plant	Seeds/ plant	Shoot dry weight (g)
Galabat	81.8 [b]	57260.0 [b]	9.02 [a]
Sumsum	53.8 [h]	37683.3 [d]	3.96 [c]
Gadarif	109.5 [a]	76626.7 [a]	4.98 [b]
Butana	42.2 [j]	29516.5 [e]	1.01[e]
Fau	58.8 [f]	41183.3 [c]	1.59 [d]
Mean	69.22	48453.96	4.112
SE ±	0.154	2.297	0.045
CV %	11.6	11.6	8.0

* Means in the same column followed by the different letter(s) are significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$.

التباين في عشائر البُودا *Strigahermonthica* (Del.) Benth, في منطقة القضارف، شرق السودان

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المستخلص:

أُجريت مسوحات حقلية خلال الموسم المطير 2009/2008، في منطقة القضارف، شرق السودان، لبحث التباين في البُودا (*S.hermonthica*) فيما يتعلق بسمات الشكل الظاهري. اختيرت خمس مواقع عشوائيا؛ القلابات، سمسم، القضارف، البطانة والفاو؛ في المناطق الموبوءة بالطفيل في شرق السودان. تم تحديد التباين في عاشر البودا بقياس سمات الشكل الظاهري والزهرة. جمعت البيانات عن سمات الشكل الظاهري وأخضعت للتحليل الوصفي وتحليل التباين (ANOVA). تمت مقارنة المتوسطات بواسطة اختبار دنكن (DMRT، $P \leq 0.05$). أُخضعت البيانات عن سمات الزهرة للتحليل الوصفي وتم مقارنتها بالمفتاح التصنيفي. أظهرت نتائج المسوحات سيادة البودا على الأنماط الوراثية للذرة في منطقة القضارف. أظهرت عشائر البودا التي جمعت من مناطق مختلفة في منطقة القضارف، اختلافات معنوية في سمات الشكل الظاهري. بينما الاختلافات في شكل، حجم ولون الزهرة عادة غير معنوية. تراوحت متوسط ارتفاع البودا بين 49.7 و 76.6 سم، تراوح إنتاج الأوراق بين 42.4 و 81.7، تراوح عدد السلاميات بين 21.3 و 41.4 وتراوحت الكثافة بين 17.4 و 33.8 نبات / م^2. تراوح متوسط الكبسولات للنبات بين 42.2 و 109.5، تراوح عدد البذور للطفيل الواحد بين 29516.5 و 76626.7 وتراوح الوزن الجاف للمجموع الخضري للطفيل بين 1.01 و 9.02 جم.تراوح متوسط أضلاع الكأس بين 3.5 و 5.7، تراوح عرض الزهرة بين 1.8 و 2 سم، تراوح طول أنبوب التويج بين 1.7 و 1.9 سم، تراوح عرض الأقواس بين 2.2 و 2.5 سم، والسنابل ذات أزهار لونها وردي يتحول للون الغامق عند التجفيف. التباينات في سمات الشكل الظاهري والزهرة في هذه الدراسة يمكن أن تنسب إلى عدد من المتغيرات تتضمن الحجم الابتدائي لمخزون البذور، أنواع، سلالات وتباينات الطفيل، النمط الوراثي للمحصول، الإدارة وأحوال المناخ والتربة والتي تتضمن المسافات، خصوبة التربة وحالة رطوبة التربة.