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PARTICIPATORY EVALUATION AND AGRO-MORPHOLOGICAL CHARACTERIZATION OF PEA GENOTYPES IN DRY ENVIRONMENTS

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ABSTRACT

Pea productivity in Yemen remains low, partly due to the limited field testing of improved varieties under actual farming conditions. This study was conducted to evaluate and characterize both improved and local pea varieties based on their qualitative and quantitative traits, with the aim of promoting their adoption by farmers. Field trials were carried out at research stations and on farmers' fields using a randomized complete block design (RCBD) with three replications at each location. A total of 29 agro-morphological traits were assessed and described. Analysis of variance (ANOVA) revealed highly significant differences ($p \leq 0.01$) among the varieties for key traits such as days to flowering, pod length, biomass, grain yield, and 100-seed weight. The improved variety 'Yahsb' recorded the highest yield of 2.7 tons/ha in the Al-Hada district, while the 'Amran' variety performed best at the research station. In comparison, the highest yield among local varieties was 1.8 tons/ha across both locations. Cluster analysis showed a 93% genetic similarity among the improved varieties, reflecting strong agreement between farmer evaluations and researcher selections. Based on these findings, several improved varieties have been recommended for cultivation in the studied districts and similar agro-ecological zones. Furthermore, participatory variety evaluation proved to be an effective and economical approach for identifying farmer-preferred varieties, thereby accelerating their adoption and contributing to enhanced pea productivity in Yemen.

Keywords: Cluster analysis, Evaluation, Phenotypic, Productive traits

Pea (*Pisum sativum* L.) is a food leguminous crop that grows in sub-tropical, temperate and high-altitude regions, used as dry grains and fresh green ripe grains when used with vegetables as green leaves and as fodder. Different species are typically used for livestock feed as above-ground mass (field pea, *P. sativum* var. arvense (L.) Poir) or as seed (dry pea, ssp. sativum), and for human consumption as pods or immature seeds (garden pea, var. Hortense (Neilr.). Based on the genetic diversity proposed by Vavilov (1926), Central Asia, the Near East, Ethiopia, and the Mediterranean were identified as four centers of origin for peas. The replacement of original strains with modern varieties, especially replacement with varieties that are characterized by resistance to biotic and non-biotic stress, is widespread and causes a loss of genetic diversity and thus narrowing of the genetic base. This may lead to the risk of genetic uniformity and a lack of diversity.

Based on studies on peas' ability to adapt to drought, it is possible to categorize plant drought resistance mechanisms into four types: drought escape, drought avoidance, drought tolerance, and drought recovery (Fang and Xiong, 2015; Weary *et al*., 1994). Some evidence has shown that the reason for the choice of *P. abyssinicum* by humans is its early flowering, which was very important to escape the drought seasons (reviewed by Coyne *et al*., 2020). Also, Naim-Feil *et al*. (2017) have pointed out that some traits in wild relatives of peas have promising potential to overcome drought stress, such as root system architecture and rhizome associations in *P. fulvum* as well as waxy leaves in *P. sativum.* Bashir *et al*. (2017) reported that under water stress, yield improvement in pea cultivars correlates with pod length (PL), pod width (PW) and number of pods per plant (NPP).

The characterization of plant varieties relies on a defined set of traits that enable clear differentiation among genotypes. To standardize this process, several international and regional organizations, such as the International Plant Genetic Resources Institute (IPGRI) and the International Union for the Protection of New Varieties of Plants (UPOV), have

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developed crop-specific characterization guidelines. These guidelines encompass phenotypic, yield-related, physiological, and pathological traits, which are essential for distinguishing among varieties and assessing genetic variation (UPOV, 2009). Analyses of genetic diversity among cultivars or populations are typically based on pedigree information, morphological characteristics, and molecular markers (Simioniuc *et al.*, 2002). However, morphological traits are often influenced by environmental factors, and in certain species, the level of morphological polymorphism may be insufficient. Consequently, their utility in evaluating genetic diversity is limited (Satovic, 1999; Yadav *et al.*, 2007).

Information about the evolutionary history and the various uses of different gene pools is highly valuable for effective planning in germplasm enhancement or expansion initiatives (Spillane and Gepts, 2001). In recent years, there has been a significant decline in the number of local pea varieties, leading to a corresponding loss of genetic diversity in European countries and other regions (Posvec and Griga, 2000). Zong *et al*. (2009) identified considerable gaps in the collection and *ex situ* storage of wild pea plants and landraces in gene banks. Baranger *et al*. (2004) reported a significant loss of genetic variation among pea landraces.

Yemen's national economy relies heavily on agriculture, with legume crops serving as a crucial source of protein. Each year, approximately 54,000 hectares are dedicated to cultivating legumes, which meet around 75% of the country's demand for these crops. The most significant legumes grown in rainfed conditions include Vigna, lentils, dry peas, and fenugreek. In contrast, common beans, broad beans, and peas are typically cultivated with supplemental irrigation. Among these, peas are one of the most vital staple legume crops for the national economy. Unfortunately, pea productivity is relatively low in the central highlands, primarily due to a lack of improved varieties and limited attention to the classification of different legume species. Yemeni varieties are characterized by a short maturation period, which helps them adapt to drought conditions. While improved varieties generally offer greater productivity than local ones, they have longer maturation periods and require additional irrigation, making them less preferred by farmers.

This study aims to analyze the genetic diversity among improved and local pea populations by characterizing both quantitative and qualitative morphological traits. It will identify similarities and evaluate the varieties based on their productivity and yield-related characteristics under moisture-deficient conditions in areas where peas are grown. Additionally, participatory evaluations will be conducted to identify the varieties preferred by farmers, facilitating the adoption of new varieties.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the central highlands of Yemen, specifically in the districts of Mayfa'a Ans, Al-Hada, and Atma, as well as at the Agricultural Research Station in Dhamar Governorate. These locations are representative of arid to semi-arid agro-ecological zones. In each district, field trials were established in three villages, with each village serving as a replicate in the experimental design.

Mayfa'a Ans District, located in the eastern part of the governorate, lies at an altitude ranging from 2,300 to 2,700 meters above sea level and receives an average annual rainfall of 100-250 mm. Al-Hada District, situated in the northern region, has elevations between 2,000 and 2,900 meters, with annual precipitation ranging from 200 to 350 mm. Atma District, in the western part of the governorate, spans altitudes from 700 to 2,500 meters and records higher annual rainfall, between 400 and 700 mm. The Agricultural Research Station is centrally located in Dhamar Governorate at an altitude of approximately 2,400 meters, with average annual precipitation ranging from 250 to 300 mm.

Treatments and design

Three varieties were evaluated, including a local variety and two improved (Yahsb and Amran) obtained from the Northern Highlands Research Station, Agricultural Research and Extension Authority. The local variety was obtained from the farm. Quantitative and Qualitative traits were described for two growing seasons, 2020 and 2021. Yield-related traits (days to flowering, days to maturity, plant height, pod length, number of seeds per pod, biomass, grain yield, and hundred-seed weight) were evaluated in farmers' fields and the research station for one growing season, 2021. The trial was conducted in a randomized complete block design with three replications from the first week to mid-July. The plot area of the trial was 3 m × 2m, spacing was 1m, 0.5m, 0.5 m, and 0.1m between replications, plots, rows, and plants, respectively.

Data collection

Quantitative characteristics: The data collected are stem length, number of nodes per raceme, leaflet length, stipules size, flowering period, number of flowers per raceme, pod length, pod width, the number of sites per green pod, seed weight, maturity period, seed weight, and biological weight.

Qualitative characteristics: The data collected are the presence of anthocyanin pigment on the stem, presence of ribs on stem, the degree of green color of the plant, the appearance of the central vein of the leaf, the presence of stipules, dots on the leaf, leaf edges, color of flower, pod curvature, pod color, shape of the seed, seed color, and the color of the cotyledon, the presence of spots on the seed and the color of pit of seed.

A total of 75 farmers (58 men and 17 women) participated in the participatory varietal evaluation process, which was conducted across the study districts. In Al-Hada District, 28 male and 7 female farmers were involved, while in Atma District, 30 male and 10 female farmers participated. The evaluation process included group discussions among participants to facilitate collective decision-making. Farmers assessed the varieties based on a set of agreed-upon selection criteria, which included plant height, flowering period, earliness, productivity, plant establishment, overall performance, and biological yield. Based on these criteria, both improved and local varieties were ranked on a scale from 1 to 3.

Data analysis

Growth, yield traits, and their components were statistically analyzed using the GenStat software (9th edition). The significance of differences among means was determined using the Least Significant Difference (LSD) test. Data collected from farmers' evaluations were analyzed using a simple value-based ranking method, as described by De Boef and Thijssen (2007). This method is commonly employed to identify promising varieties based on farmers' preferences. The ranking procedure was clearly explained to all participating farmers, who then established a set of selection criteria. Each variety was scored on a scale of 1 to 5 for each criterion, where 5 = very good, 4 = good, 3 = average, 2 = poor, and 1 = very poor. Rankings were developed through group consensus, with any disagreements resolved through discussion (De Boef and Thijssen, 2007).

Cluster analysis was performed on phenotypic traits using multivariate analysis, as these traits were considered multi-categorical. For each trait, average values were calculated and then classified based on the degree of variation among varieties. These averages were scaled from 1 to 5, representing the relative performance of each variety. Phenotypic data were further analyzed using pre-defined characterization descriptors, and the analysis was carried out in GenStat (9th edition) following established procedures (Hammer *et al.*, 2001).

Quantitative and qualitative data were recorded as shown in Table 1 and 2. All data were recorded from five plants per row in each experimental plot.

RESULTS AND DISCUSSION

Agronomic traits of varieties and farmer's variety evaluation at Mayfa'a Ans

The mean values for days to flowering, days to maturity, plant height, pod length, number of seeds

Table 1. Keys for quantitative traits of pea

Sr. No.	Trait	Keys
1	Stem height (cm)	1=Very short (30), 3=Short (40), 5=Intermediate (60)
2	Number of nodes per raceme	1=Very less (3), 3=Less (4), 5=Intermediate (5), 7=Much (6)
3	Leaflet length (cm)	1=Very short (2), 3=Short (3), 5=Intermediate (4), 7=Tall (5)
4	Leaflet width (cm)	2=Tight (one), 3=Medium (tow), 5=Wide (three)
5	Stipules length (cm)	1=Very short (2), 3=Short (2), 5=Intermediate (4), 7=Tall (5)
6	Days to flowering (day)	2=Early (30-39), 3=Medium (40-49), 5=Late (more than 50)
7	Number of flowers per raceme	1=Law (tow), 2=Medium (five), 3=Hight (more than five)
8	Pod length (cm)	1=Very short (3), 3=Short (4), 5=Intermediate (5), 7=Tall (7)
9	Pod width (cm)	2=Tight (0.5-0.8), 3=Medium (1-1.2), 5=Wide (more than 1.5)
10	The number of sites per pod	2=One, 3=Two, 5=Three, 7=Four, 9=More than four
11	Seed width (gm)	1=Law (10-15), 2=Medium (16-30), 3=Hight (more than 30)
12	Days to maturity (day)	2=Early (70-80), 3=Medium (81-90), 5=Late more than (95)

Table 2. Keys for qualitative traits of pea

Sr. No.	Trait	Keys
1	Anthocyanin pigment on the stem	1=Absent, 2=Single ring, 3=Double ring
2	Presence of ribs on stem	1=Absent, 9=Present
3	Intensity of green color	3=Pale, 5=Intermediate, 7=dark
4	The middle vein of the leaf	1=Very slightly, 3=Slightly, 5=Intermediate, 7=Clear
5	The presence of stipules	1=Absent, 9=Present
6	Dots on the leaf	1=Absent, 9=Present
7	Leaf edges	1=Serrated, 2=Non-serrated
8	Color of flower	1=White, 2=Cream, 3=Purple
9	The shape of the flower base	1=Very high, 2=High, 3=Mediate, 5=Straight
10	The shape of the sepal apex of the flower	1=Peaked, 2=Semi-peaked, 3=Circular,
11	Pod curvature	1=Slight, 2=Curved
12	Pod color	1=Yellow, 3=Green, 5=Green bluish, 7=Purple
13	Shape of seed	1=Cylindrical, 2=Diamond, 5=Irregular, 7=Spherical
14	Seed color	1=Green light, 2=Green dark, 3=Brown, 5=White
15	Cotyledon color	1=Green, 2=Yellow, 3=Orange, 5=Brown
16	The presence of spots on the seed	1=Absent, 2=Present
17	Colour of pit of seed	1=Same color seed, 2=Dark from seed

per pod, biomass, grain yield, and hundred-seed weight are presented in Table 3. Analysis of variance revealed highly significant differences ($p \leq 0.01$) among the pea varieties for several traits, including days to flowering, plant height, grain yield, biomass, and hundred-seed weight. The highest grain yield was recorded in the variety Amran (1,670 kg/ha), followed closely by Yahsb (1,650 kg/ha), while the local variety produced the lowest yield (1,290 kg/ha).

Agronomic traits of varieties and farmer's variety evaluation at AL-Hada

The mean values for days to flowering, days to maturity, plant height, pod length, number of seeds per pod, biomass, grain yield, and hundred-seed weight are presented in Table 5. Significant differences ($p \leq 0.05$) were observed among the varieties for days to maturity, while highly significant differences ($p \leq 0.01$) were detected for days to flowering, plant height, pod length, biomass, grain yield, and hundred-seed weight. The highest grain yield was recorded in the variety Yahsb (2,710 kg/ha), followed by Amran (2,250 kg/ha), whereas the local variety produced the lowest yield (1,730.7 kg/ha).

Based on the farmers' selection criteria, Yahsb received the highest overall ranking score (32.7), followed by Amran (30.5), while the local variety received the lowest score (27.0), as shown in Table 4. These results suggest that varieties developed for specific agro-ecological niches may also have the potential to perform well in other, ecologically distinct environments.

Agronomic traits of varieties and farmer's variety evaluation at Atma

Agronomic traits including days to flowering, days to maturity, plant height, pod length, number of seeds per pod, biomass, grain yield, and hundred-

Table 3. Agronomic characters of varieties at Mayfa'a Ans

Variety	GY kg/ha	BM kg/ha	DM	SW (100g)	SPD	PL (cm)	DF	PH (cm)
Local	1290.33	3360.7	73.33	12	6.67	4.33	40	40
Yahsb	1640.67	3920.7	80.67	18	7.00	5.67	55	70
Amran	1670.00	3900.0	85.33	19	7.00	5.67	55	70
Means	1530.67	3730.1	79.78	16.33	6.9	5.22	50	60
LSD ($p \leq 0.05$)	*7.75***	*33.83***	*3.027**	*2.472***	*NS*	*1.153**	*6.054***	*5.243***

Table 4. Mean of farmer's selection criteria and ranking of varieties at AL-Hada

Variety	GY	PES	ER	SW	BM	OAP	Total	Mean	Rank
Local	25	25	35	25	25	27	162	27.00	3
Amran	33	32	28	30	30	30	183	30.5	2
Yahsb	*35*	*35*	*28*	*35*	*30*	*33*	*196*	*32.7*	*1*

where: OAP = Overall performance, ER = Earliness, GY = Grain yield (kg/ha), SW = Seed weight, PES = Plant establishment and BM = Biomass

Table 5. Agronomic characters of varieties at AL-Hada

Variety	GY kg/ha	BM kg/ha	DM	SW (100g)	SPD	PL (cm)	DF	PH (cm)
Local	1730.7	6140.7	81	10.67	6.67	4.00	40	44.7
Yahsb	2710.0	7670.0	91.0	17.00	7.00	6.67	70.00	70.0
Amran	2250.0	7140.3	91.0	18.00	7.00	5.67	69.33	70.0
Mean	2230.2	6980.7	87.7	15.22	6.9	5.44	59.78	61.6
LSD ($p \leq 0.05$)	*12.15***	*17.7***	*6.21**	*7.9***	*NS*	*1.43***	*8.259***	*12.40***

where: DF = Days to flowering, DM = Days to maturity, PH = Plant height, SPD = Seeds per pod, BM = Biomass (kg/ha), GY = Grain yield (kg/ha), PL = Pod length, SW = Seed weight
** = Highly significant, * = Significant, NS = Non-significant, LSD = Least significant difference

Table 6. Agronomic characters of varieties at Atma

Variety	GY kg/ha	BM kg/ha	DM	SW (100g)	SPD	PL (cm)	DF	PH (cm)
Local	1600.0	7050	75.33	13.00	4.67	5.67	48.67	52.3
Yahsb	1850.0	6500	81.67	16.00	6.33	6.67	71.67	64.0
Amran	1950.7	7250	82.67	17.00	6.67	6.33	68.33	62.0
Mean	1800.2	6930	79.89	15.33	5.89	6.22	62.89	59.4
LSD ($p \leq 0.05$)	*15.37***	*NS*	*4.46**	*3.027***	*1.15**	*NS*	*8.95***	*9.7***

where: DF = Days to flowering, DM = Days to maturity, PH = Plant height, SPD = Seeds per pod, BM = Biomass (kg/ha), GY = Grain yield (kg/ha), PL = Pod length, SW = Seed weight
** = Highly significant, * = Significant, NS = Non-significant, LSD = Least significant difference

Table 7. Mean of farmers selection criteria and ranking of varieties at Atma

Variety	GY	PES	ER	SW	BM	OAP	Total	Mean	Rank
Local	30	30	35	30	33	33	191	31.8	3
Yahsb	40	35	33	40	38	35	221	36.8	2
Amran	*40*	*38*	*33*	*40*	*38*	*38*	*227*	*37.8*	*1*

where: OAP = Overall performance, ER = Earliness, GY = Grain yield (kg/ha), SW = Seed weight, PES = plant establishment and BM = biomass

seed weight were analyzed and are presented in Table 6. Significant differences ($p \leq 0.05$) were observed among the varieties for days to maturity and the number of seeds per pod, while highly significant differences ($p \leq 0.01$) were recorded for days to flowering, plant height, grain yield, and hundred-seed weight. The highest grain yield was obtained from the variety Amran (1,950 kg/ha), followed by Yahsb (1,850 kg/ha), whereas the local variety recorded the lowest yield (1,600 kg/ha).

According to the participatory selection criteria, farmers ranked Amran highest with a score of 37.80, followed by Yahsb (36.80), while the local variety received the lowest ranking (31.80), as shown in Table 7. The involvement of farmers in evaluating and selecting varieties proved to be an effective approach, leveraging their practical knowledge and experience to identify well-adapted genotypes that meet local production and preference requirements.

Table 8. Agronomic characters of varieties at the station

Variety	GY kg/ha	BM kg/ha	DM	SW (100g)	SPD	PL (cm)	DF	PH (cm)
Local	1740.0	5050.0	75.67	11.67	6.33	4.00	39.33	31.67
Yahsb	2420.0	8130.3	82.67	20.67	7.00	6.33	61.67	68.33
Amran	2720.0	6900.3	79.67	21.33	6.78	6.67	58.33	68.33
Mean	2290.3	6690.6	79.33	17.89	6.70	5.89	53.11	56.11
LSD ($p \leq 0.05$)	*16.30***	*41.38***	*3.26**	*2.45***	*NS*	*1.153**	*7.42***	*8.73***

where: DF = Days to flowering, DM = Days to maturity, PH = Plant height, SPD = Seeds per pod, BM = Biomass i(kg/ha), GY = Grain yield (kg/ha), PL = Pod length, SW = Seed weight
** = Highly significant, * = Significant, NS = Non-significant, LSD = Least significant difference

Farmer preferences and variety ratings

Farmers who participated in the participatory variety selection process identified approximately six key evaluation traits (Tables 4 and 7). Although a range of characteristics was considered, only a few were consistently emphasized across locations. This observation aligns with findings from a previous study by Asfaw *et al.* (2012) on common beans, where farmers evaluated new varieties using a combination of a limited number of critical traits. In the current study, the most important factors influencing farmers' selection of pea varieties included overall crop performance, yield, seed size, and earliness. Earliness emerged as a decisive trait, as it enables crops to escape terminal drought-an increasingly important consideration in arid and semi-arid regions.

Based on individual interviews conducted at both sites, the majority of farmers preferred varieties that were disease-resistant, high-yielding, and had good pod length. These criteria were key in deciding whether to retain or reject a variety. Although farmers shared similar impressions on many traits, the 'Yahsb and Amran' varieties outperformed the local variety.

Additionally, Vom *et al*. (2010) pointed out that because good traits are rarely found in a single variety, having a broader range of selection criteria helps maintain diversity on the farm. The current selection process at both sites demonstrated farmers' ability to identify important traits (crop components), leading to the identification of superior varieties that are well-adapted to their environment. This study highlighted the significant role of the participatory approach, which was comparable to traditional plant breeding methods.

Phenotypic description

Qualitative traits

Table 9 presents the values of 17 phenotypic descriptors used to distinguish among the evaluated pea varieties. These traits enabled clear differentiation at the morphological level. The improved varieties (Yahsb and Amran) differed from the local variety in nine descriptive characteristics. The improved varieties exhibited anthocyanin pigmentation and ribbed stems, whereas the local variety was characterized by serrated leaf margins, features

Table 9. Morphological characterization of pea genotypes based on qualitative traits

Sr. No.	Trait	Local variety	Yahsb variety	Amran variety
*1	APS	1	2	2
*2	RS	1	9	9
*3	DGC	5	5	7
*4	MVL	3	3	3
*5	PS	9	9	9
*6	DL	1	1	1
*7	LE	1	2	2
*8	CF	3	1	1
*9	SFB	3	3	3
*10	SSAF	1	1	1
*11	PC	3	5	5
*12	PCO	1	1	1
*13	SS	5	7	5
*14	SC	3	1	2
*15	CC	2	2	2
*16	SOS	1	1	1
*17	CPS	2	1	1

where: *1: 1 = Absent, 2 = Single ring, *2: 1 = Absent, 9 = Present, *3: 5 = Intermediate, 7 = dark, *4: 3 = Slightly, *5: 9 = Present, *6: 1 = Absent, *7: 1 = Serrated, 2 = Non-serrated, *8: 1 = White, 3 = Purple, *9: 3 = Mediate, *10: 1 = Peaked, *11: 3 = Straight, 5 = Slightly, *12: 1 = Yellow, *13:5 = Irregular, 7 = Spherical, *14: 1 = Green light, 2 = Green dark, 3 = Brown, *15: 2 = Yellow, *16: 1 = Absent, *17: 1 = Same color seed,2 = Dark from seed absent in the improved lines.

Flower color also varied among varieties, the improved varieties had white flowers, while the local variety displayed purple flowers. Pod shape differed as well, with the improved varieties having slightly curved pods compared to the straight pods of the local variety. Seed color was another distinguishing trait, the local variety had brown seeds, Yahsb had light green seeds, and Amran had dark green seeds. Furthermore, the seed pits of the local variety were darker than the seed surface, whereas the improved varieties had uniform seed and pit coloration.

In terms of seed shape, Yahsb was characterized by spherical seeds, while both Amran and the local variety had irregularly shaped seeds. Variation in plant color was also observed, Yahsb and the local variety exhibited a medium green hue, while Amran displayed a darker green coloration. These findings are consistent with those reported by Belul *et al.* (2014), who identified phenotypic variation across 12 local pea varieties based on 23 morphological traits.

Table 10 presents the values of 12 quantitative traits that enabled clear phenotypic differentiation among the evaluated pea varieties. The improved varieties (Yahsb and Amran) differed from the local variety in 11 of the 12 traits assessed.

A significant difference was observed in stem length, with the improved varieties averaging 65 cm, compared to 40 cm in the local variety. Similarly, the number of nodes per stem averaged seven in the improved varieties, while the local variety had only five. Regarding leaf morphology, the improved varieties had longer and broader leaves, with average leaf lengths and widths of 3 cm and 2 cm, respectively, compared to 2 cm and 1 cm in the local variety.

Stipule length also varied: the improved varieties exhibited medium-sized stipules averaging 4 cm, while the local variety had shorter stipules averaging 3 cm. In terms of flowering time, the local variety was early-flowering (40 days), whereas Yahsb and Amran were later flowering at 65 and 60 days, respectively.

For reproductive traits, the local variety produced an average of one flower per node, while the improved varieties produced two flowers per node. Pod characteristics also differed significantly: the improved varieties had longer pods (average 6 cm) compared to the local variety (4 cm). Pod width was greater in Amran (1.5 cm) and Yahsb (1.3 cm), while the local variety had narrower pods, averaging 1 cm.

In terms of maturity, the local variety matured earlier (75 days), while Yahsb and Amran matured at around 85 days, classifying them as medium-maturing varieties. Seed size also varied, with the local variety producing smaller seeds (12 g per 100 seeds), compared to medium-sized seeds in Yahsb (17 g) and Amran (19 g).

All three varieties were similar in only two traits, the number of ovule sites per pod and the number of seeds per pod, both exceeding four in all cases. These findings are consistent with those reported by Tar'an *et al.* (2005), who found that cultivated pea varieties exhibited significant genetic differences from wild types based on key agronomic traits.

Genetic relatedness between cultivars based on phenotype using the UPGMA method

Cluster analysis grouped the varieties into two main clusters (Fig. 1). The first cluster comprised the improved varieties Yahsb and Amran, which exhibited a high degree of relatedness (93%), suggesting that they may belong to the same species or share a common genetic background. The second cluster included the local variety, which showed a considerably lower degree of relatedness

Table 10. Agronomic and yield related traits of three pea varieites

Sr. No.	Trait	Local variety	Yahsb variety	Amran variety
*1	SH	1	2	2
*2	NNR	3	7	7
*3	LL	5	5	7
*4	LW	3	3	3
*5	SL	9	9	9
*6	DF	2	5	5
*7	NFR	1	2	2
*8	PW	3	3	3
*9	NSP	9	9	9
*10	PL	3	5	5
*11	DM	2	3	3
*12	SW	1	2	2

where: *1: 1 = Very short, 2 = Short, *2: 3 = Less, 7 = Much, *3: 5 = Intermediate, 7 = Tall, *4: 3 = Medium, *5: 9 = Very tall, *6: 2 = Early, 5 = Late, *7: 1 = Low, 2 = Medium, *8: 3= Medium, *9: 9= More than four, *10: 3 = Short, 5 = Intermediate, *11: 2 = Early, 3 = Medium, *12: 1 = Low, 2 = Medium

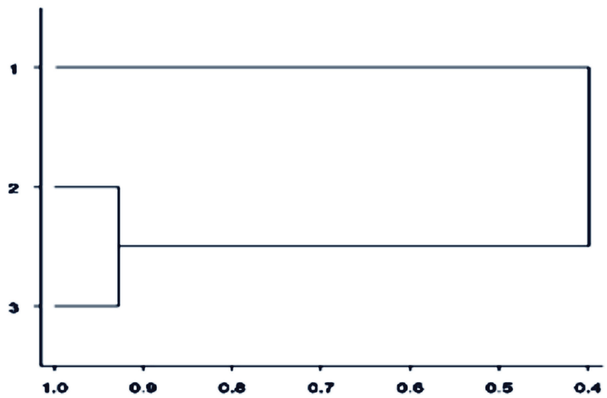

Fig. 1 **Relationship among pea genotypes revealed by cluster analyses 1 = Local, 2 = Yahsb, 3 = Amran**

(40%) to the improved varieties. These results highlight clear genetic and phenotypic distinctions between the local and improved varieties, possibly reflecting differences in both genetic makeup and environmental adaptation.

CONCLUSION

Cluster analysis effectively classified the pea genotypes into two distinct groups, facilitating the identification of genetic similarities among pea varieties of 'unknown' or 'introduced' origin from other regions. Yield increases for the improved varieties Yahsb and Amran were substantial, with gains of 900 kg/ha and 500 kg/ha, respectively recorded in Al Hada, 700 kg/ha at the research station, and 400 kg/ha in Atma, compared to the local variety.

Farmers played a vital role in the evaluation and selection process, contributing valuable insights that helped identify varieties best suited to local needs and preferences. The improved varieties demonstrated high adaptability and consistently outperformed local variety in both yield and farmer rankings. Based on the combined preferences of farmers and researchers, Yahsb and Amran are recommended for cultivation in the central highlands and other similar agro-ecological zones.

Authors' contribution

Conceptualization of research work and designing of experiments (MM[1], MM[2], TA[3]); Execution of field experiments and data collection (MM[1], MM[2], TA[3]); Analysis of data and interpretation (MM[1]); Preparation of manuscript (MM[1]).

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