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Morphological characterization of genotypes of vegetable pea (*Pisum sativum* L. spp. *hortense*) in North East India

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Abstract
Legumes stand as pivotal crops globally, exerting substantial influence across agriculture, environmental sustainability, and both animal and human nutrition. The garden pea (*Pisum sativum* L.), a member of the Leguminosae (Fabaceae) family, occupies a noteworthy place in agricultural history, tracing its significance back to the pioneering genetic research conducted by Gregor J. Mendel, the founding figure of genetics. The study at hand encompasses an assemblage of 30 distinct pea genotypes as experimental material. Our meticulous observations span a comprehensive array of morphological attributes within garden pea plants, encompassing stem color, stem anthocyanin pigmentation, leaf type, stipule size and shape, number of leaflet pairs, leaf blade arrangement, tendrils disposition, growth habits, flower hues, flowering patterns, pod shapes, pod end configurations, and pod colors. These findings are poised to greatly benefit breeders involved in enhancing pea varieties through the strategic process of selective introgression breeding.

Keywords: Garden pea, morphological, traits, breeding

Introduction
Legumes play a crucial role in global agriculture, exerting significant impacts on various fronts such as environmental sustainability, animal and human nutrition, and the overall agricultural landscape (Graham and Vance, 2003) [5]. These versatile crops engage in symbiotic partnerships with specialized soil-dwelling bacteria known as Rhizobia, a relationship that enables them to harness atmospheric nitrogen, enhance soil structure, and potentially fend off specific fungal adversaries (Chakraborty *et al.*, 2003) [1]. Within the legume family, pea (*Pisum sativum* L.), a member of the Leguminosae (Fabaceae) family, stands out as a cornerstone crop with an extensive genetic research heritage tracing back to the pioneering studies of genetics pioneer Gregor J. Mendel.

As one of the world's six primary pulse crops, pea holds a prominent global cultivation status, securing its place as the second most productive legume worldwide, trailing only behind the common bean (*Phaseolus vulgaris* L.). Unearthed relics from archaeological digs substantiate the pea's historical presence, tracing its roots back to 10,000 B.C. in regions spanning the Near East and Central Asia (Zohary and Hopf, 1973) [14].

Pea (*Pisum sativum* L.) stands as a resilient and nourishing leguminous gem, well-equipped to brave frosty conditions and thrive in cool seasons. This esteemed garden vegetable flourishes in the chillier months, meticulously self-pollinating as it matures into a succulent, youthful state, perfect for immediate consumption or preservation through canning and freezing. Exhibiting a yearly herbaceous cycle, pea boasts a tap root system and graceful, solitary upright stems. Its foliage is a marvel of pinnate complexity, adorned with two to several leaflets, while a simple or intricately branched tendril graces the rachis's end. Notably, ample stipules grace the leaf bases, adding to the plant's allure. Bursting forth from leaf axils, raceme inflorescences proudly bear papilionaceous flowers, wherein a green calyx harmonizes five united sepals with five petals. The saga of peas often leads to processing canning, freezing, and dehydration providing a year-round delicacy. Esteemed for both its vibrant green pods and the bounty of dried seeds it yields, pea takes the spotlight for its protein excellence, particularly in lysine, a pivotal amino acid often limited in cereals.

Beyond its protein prowess, pea gleams with a treasure trove of nutrients, boasting vitamins A, B, and C, a medley of minerals, dietary fibre, and a suite of antioxidant champions (Urbano *et al*., 2003) [13]. Remarkably, pea continues to shine as a nutritional powerhouse, a protein source boasting 7.2g per 100g (Singh *et al.*, 2007) [12]. Its appeal spans continents, cherished both as a verdant Asian delight embracing whole pods and nascent seeds and as a dry seed marvel across Europe, Australia, the Americas, and the Mediterranean realm (Ghafoor *et al*., 2008) [4].

Despite its significant economic significance, pea production per unit area remains modest within the country, particularly when cultivating varieties during off-seasons. This deficiency can largely be ascribed to the dearth of high-yielding pea varieties that possess inadequate or absent resistance against powdery mildew and Fusarium wilt. Consequently, an imperative task beckons to meticulously assess a substantial array of genotypes, thereby pinpointing the cream of the crop in terms of high yield and exceptional quality among pea varieties. Such exceptional cultivars could be expedited for direct integration into commercial production, or thoughtfully incorporated into forthcoming crop enhancement initiatives, with a particular focus on bolstering yield and refining the gamut of quality attributes.

Materials and Methods

Conducted at the Vegetable Research Farm within the Department of Vegetable Science at the College of Horticulture and Forestry, Central Agricultural University in Pasighat, Arunachal Pradesh, the current study bears the title "Morphological characterization of genotypes of vegetable pea (*Pisum sativum* L. spp. *hortense*) in North East India." The ensuing section provides a comprehensive account of the materials employed and the methodologies adopted in the pursuit of this investigation.

Experimental details

1	Crop	Pea (*Pisum sativum* L.)
2	Design of experiment	Randomize Block Design
3	Replications	3
4	Number of genotypes	30
5	Total number of plots	90
6	Plot size	2.5 x 2.5m
7	Spacing	30 x 10 cm

Experimental materials

For the present study, a selection of 30 distinct pea genotypes (*Pisum sativum* L.) served as the experimental foundation. The complete roster of these genotypes, coupled with their respective origins, is thoughtfully documented in Table 1.

Table 1: List of pea genotypes with their sources

Sl. No.	Genotypes	Sources
1	CHFP-1	IIVR, Varanasi
2	CHFP-2	IIVR, Varanasi
3	CHFP-3	IIVR, Varanasi
4	CHFP-4	IIVR, Varanasi
5	CHFP-5	IIVR, Varanasi
6	CHFP-6	IIVR, Varanasi
7	CHFP-7	IIVR, Varanasi
8	CHFP-8	IIVR, Varanasi
9	CHFP-9	IIVR, Varanasi
10	CHFP-10	IIVR, Varanasi
11	CHFP-11	IIVR, Varanasi
12	CHFP-12	IIVR, Varanasi
13	CHFP-13	IIVR, Varanasi
14	CHFP-14	IIVR, Varanasi
15	CHFP-15	IIVR, Varanasi
16	CHFP-16	IIVR, Varanasi
17	CHFP-17	IIVR, Varanasi
18	CHFP-18	IIVR, Varanasi
19	CHFP-19	Khergao, Manipur
20	CHFP-20	Thoubal, Manipur
21	CHFP-21	Lamphel, Manipur
22	CHFP-22	Noney, Manipur
23	CHFP-23	A landrace of Aizawl, Mizoram
24	CHFP-24	A Landrace of Barapani, Meghalaya
25	CHFP-25	A landrace of Sikkim
26	CHFP-26	A landrace of Tripura
27	CHFP-27	Arkel variety
28	CHFP-28	A landrace of Dimapur, Nagaland
29	CHFP-29	A landrace of Arunachal Pradesh
30	CHFP-30	A landrace from Assam

Morphological characters

The morphological traits outlined below were characterized according to the provided descriptors

1. **Stem Colour:** Stem coloration was assessed at the full foliage stage, resulting in categorizations Green / Light Green / Dark Green.
2. **Anthocyanin Colouration in Stem:** During the crop's full growth stage, the presence or absence of anthocyanin coloration was noted as Present / absent.
3. **Leaf Type:** Different leaf types were identified at the full foliage stage, leading to classifications Acacia / Normal / Others.
4. **Stipule Size:** Stipule size was determined in relation to leaflets, with traits categorized as Small / Large / Same Size / Others.
5. **Stipule Shape:** Stipule shape was observed in accordance with stipule structure, resulting in classifications Clasping / Open.
6. **Number of Leaflet Pairs:** At the full foliage stage, the count of leaflet pairs on 10-20 leaves was recorded as Single / Double / Triple / Not Paired.
7. **Arrangement of Leaf Blades:** During the same full foliage stage, the arrangement of leaf blades on 10-20 leaves was noted as Symmetrical / Asymmetrical.
8. **Arrangement of Tendrils:** The arrangement of tendrils on 10-20 leaves, assessed at the full foliage stage, was recorded as Symmetrical / Asymmetrical.
9. **Plant Growth Habit:** Upon reaching the completion of the vegetative stage, the plant's growth habit was observed and ranked as erect / Semi-erect / Spreading / Bushy.
10. **Flower Colour:** The colour of freshly opened flowers in the early morning was noted, resulting in categories White / Blue / Pink / Purple.
11. **Flowering Habit:** The flowering habit of the crop at the full blooming stage was categorized as Synchronous /

Asynchronous / Intermediate / Others.

12. **Pod Shape:** Randomly selecting ten pods, their shapes were visually categorized as Straight / Slightly Curved / Curved / Highly Curved.
13. **Pod End Shape:** The end shape of ten randomly selected pods was visually assessed and categorized as Straight / Slightly Curved / Curved / Highly Curved.
14. **Pod Colour:** Pod colour, as observed on randomly selected pods at the marketable stage, was visually classified as Dark Green / Light Green / Green.

Results

Observations were meticulously recorded for a range of morphological characteristics within the garden pea plant. These traits encompassed stem colour, anthocyanin coloration in the stem, leaf type, stipule size, stipule shape, number of leaflet pairs, arrangement of leaf blades, arrangement of tendrils, plant growth habit, flower colour, flowering habit, pod shape, pod end shape, and pod colour. Elaborative insights into these various morphological traits are provided in Table 4.1.

Stem colour was predominantly green in genotypes CHP-1, CHFP-2, CHFP-3, CHFP-4, CHFP-20, CHFP-21, CHFP-22, CHFP-23, CHFP-24, CHFP-25, CHFP-26, and CHFP-27. A lighter shade of green was noted in CHFP-5, CHFP-6, CHFP-7, CHFP-8, CHFP-9, CHFP-14, CHFP-15, CHFP-16, CHFP-17, CHFP-18, CHFP-19, CHFP-28, CHFP-29, and CHFP-30.

The presence of anthocyanin coloration in the stem was evident in CHFP-19, CHFP-20, CHFP-21, CHFP-22, CHFP-24, CHFP-25, CHFP-26, CHFP-28, CHFP-29, and CHFP-30, whereas it was absent in the remaining genotypes.

Leaf types were predominantly normal in CHP-1, CHFP-2, CHFP-3, CHFP-4, CHFP-6, CHFP-9, CHFP-12, CHFP-22, CHFP-28, CHFP-25, CHFP-29, and CHFP-30. On the other hand, acacia leaf types were observed in CHFP-4, CHFP-5, CHFP-7, CHFP-8, CHFP-10, CHFP-11, CHFP-13, CHFP-14, CHFP-15, CHFP-16, CHFP-17, CHFP-18, CHFP-19, CHFP-20, CHFP-21, CHFP-24, CHFP-25, CHFP-26, and CHFP-27.

A comprehensive assessment of stipule size, shape, number of leaflet pairs, arrangement of leaf blades and arrangement of tendrils, plant growth habit, and flower colour was conducted across various genotypes. The detailed findings are as follows:

Stipule Size: Medium stipule size was observed in CHFP-2 and CHFP-23.Small stipule size was predominant in CHP-1, CHFP-5, CHFP-6, CHFP-7, CHFP-8, CHFP-9, CHFP-10, CHFP-11, CHFP-12, CHFP-13, CHFP-14, CHFP-15, CHFP-16, CHFP-17, CHFP-18, CHFP-19, CHFP-20, and CHFP-21.Large stipule size was evident in CHFP-3, CHFP-4, CHFP-22, CHFP-24, CHFP-25, CHFP-26, CHFP-27, CHFP-28, CHFP-29, and CHFP-30.

Stipule Shape: Open stipule type was identified in CHP-1, CHFP-8, CHFP-9, CHFP-10, CHFP-11, CHFP-12, CHFP-15, CHFP-16, CHFP-25, CHFP-26, CHFP-28, CHFP-29, and CHFP-30. Clasping stipule type was prevalent in the remaining genotypes.

Number of Leaflet Pairs: Double leaflet pairs were observed in CHP-1, CHFP-2, CHFP-3, CHFP-6, CHFP-9, CHFP-12, CHFP-21, CHFP-22, and CHFP-28. Triple leaflet pairs were noted in the remaining genotypes.

Arrangement of Leaf Blades: Symmetrical arrangement of leaf blades was characteristic of most genotypes, with exceptions noted in CHFP-4, CHFP-10, and CHFP-11.

Arrangement of Tendrils: Symmetrical arrangement of tendrils was observed in most genotypes, similar to the leaf blade arrangement exceptions noted in CHFP-4, CHFP-10, and CHFP-11.

Plant Growth Habit: Semi-erect growth habit was prominent in CHFP-1, CHFP-2, CHFP-3, CHFP-5, CHFP-6, CHFP-7, CHFP-8, CHFP-9, CHFP-12, CHFP-13, CHFP-14, CHFP-15, CHFP-17, and CHFP-18. Bushy growth habit was evident in CHFP-4, CHFP-10, and CHFP-11.CHFP-27 displayed an erect growth habit.

Flower Colour: The majority of genotypes exhibited white flower colour, including CHFP-1, CHFP-2, CHFP-3, CHFP-4, CHFP-5, CHFP-6, CHFP-7, CHFP-8, CHFP-9, CHFP-10, CHFP-11, CHFP-12, CHFP-13, CHFP-14, CHFP-15, CHFP-16, CHFP-17, CHFP-18, CHFP-27, CHFP-28, CHFP-29, and CHFP-30. A distinct pink-purple flower colour was observed in the remaining genotypes.

Flowering habit: Among the various genotypes, the flowering habit predominantly displayed symmetry, except for CHFP-4, CHFP-10, and CHFP-11, which exhibited asymmetry.

Pod Shape: Straight pod shape characterized CHFP-1, CHFP-2, CHFP-4, CHFP-21, CHFP-22, and CHFP-25. Slightly curved pod shape was noted in CHFP-3, CHFP-7, CHFP-8, CHFP-11, CHFP-12, CHFP-15, CHFP-20, CHFP-23, CHFP-24, CHFP-27, CHFP-28, CHFP-29, and CHFP-30. Curved pod shape was observed in CHFP-5, CHFP-6, CHFP-13, CHFP-14, CHFP-16, CHFP-17, CHFP-18, CHFP-19, and CHFP-26.

Pod End Shape: Pointed pod end shape was evident in CHFP-3, CHFP-5, CHFP-6, CHFP-7, CHFP-8, CHFP-9, CHFP-10, CHFP-11, CHFP-12, CHFP-13, CHFP-14, CHFP-15, CHFP-17, and CHFP-18.Blunt pod end shape was observed in CHFP-1, CHFP-2, CHFP-19, CHFP-20, CHFP-21, CHFP-22, CHFP-23, CHFP-24, CHFP-25, CHFP-26, CHFP-28, CHFP-29, and CHFP-30.

Pod Colour: Green pod colour characterized CHFP-1, CHFP-2, CHFP-3, CHFP-4, CHFP-5, CHFP-6, CHFP-9, CHFP-10, CHFP-11, CHFP-13, CHFP-14, CHFP-16, CHFP-18, CHFP-19, CHFP-21, CHFP-22, CHFP-23, CHFP-25, CHFP-26, and CHFP-28.Light green pod colour was found in CHFP-7 and CHFP-8, while dark green pod colour was noted in CHFP-12, CHFP-15, CHFP-24, CHFP-29, and CHFP-30.

Discussion

The genotypes under investigation exhibited a notable spectrum of phenotypic variations, which hold substantial importance in the context of breeding programs. The significance of these seemingly simple morphological traits cannot be underestimated, given their direct or indirect correlations with a plethora of economically significant traits. A striking illustration of such diversity is discernible in the coloration of flowers and seed coats, with potential linkages to antioxidant activities. In consonance with Devi *et al.*

(2019), it was established that pea genotypes featuring distinct colours and maturity types exhibited a positive correlation with total phenol and flavonoid contents. Notably, some of the genotypes were characterized by purple flowers and dark seed coats, boasted the highest total phenol and flavonoid contents accompanied by robust antioxidant potential. In comparison, their white flowered and light seed-coated counterparts paled in comparison. This nuanced insight suggests that opting for darker-hued pea genotypes could yield substantial strides in enhancing antioxidant compounds among the segregating progenies. Beyond this, comprehension of gene actions governing diverse economically relevant traits not only aids in the strategic selection of parent plants but also guides the appropriate breeding methodologies to harness genetic advancements (Sharma & Sharma, 2013) [10]. Evaluating the genetic diversity within a species yields multifaceted benefits, encompassing the formulation of conservation strategies, informed integration into breeding endeavours, and a deeper examination of crop evolution. Notably, comprehensive investigations into the genetic diversity of arid-region species have been relatively constrained thus far. Morphological characterization, being the foremost stride in germplasm delineation and classification, has garnered triumphs across a spectrum of plant species, a prime example being maize (Couto *et al.* 2013) [2], wheat (Li *et al.* 2012) [7], and indeed, pea (Jha *et al.* 2013) [6]. Categorization based on elemental phenotypic attributes serves as a venerable approach that holds strategic significance in the realm of genotype identification for hybridization endeavours, aiming to harness maximal heterosis and foster relatively superior recombinant lines. The realm of pea morphological traits has been punctuated by substantial variability, as illuminated by previous studies by Singh *et al.* (2014) [11], Mohamed *et al.* (2019) [8], and Sharma *et al.* (2022) [9].

Conclusions
The 30 genotypes accessions of *Pisum* showed considerable diversity for 14agro-morphological traits. Principal component analysis has identified few characters which play a prominent role in classifying the variation existing in the germplasm set. The present study facilitated the identification of potential accessions harbouring novel, favourable genotypes for various economically important traits.

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