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Evaluation of cashew nut (*Anacardium occidentale* L.) germplasm in North-Eastern Hilly region of Bangladesh

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ABSTRACT

Five cashew nut germplasms (AO Jai-001, AO Jai-002, AO Jai-003, AO Jai-004 and AO Jai-005) were evaluated in an experiment carried out in 2024–2025 at the Citrus Research Station, BARI, Jaintaapur, Sylhet. The experiment was conducted in a Randomized Complete Block Design with three replications. Significant variations among germplasm were noted for all the attributes evaluated. Among five cashew nut germplasm AO Jai-001 exhibited superior vegetative growth with the tallest height, highest base girth and widest spreading. Flowering was early in AO Jai-003 and maturity durations (42.67 days), potentially offering early harvest advantages. AO Jai-001 produces maximum nut yield per plant (3.52 kg), edible kernel weight per plant (1.09kg). However, based on overall growth and yield performance, AO Jai-001 and AO Jai-003 were identified as promising germplasm for cultivation in the north-eastern hilly region of Bangladesh.

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INTRODUCTION

Cashew (*Anacardium occidentale* L.) is a high-priced fruit tree, from the Anacardiaceae family (Rao and Swamy, 1994). Cashew is a long-living, evergreen and tropical tree that can grow up to about 14m and its canopy can spread 25 m (Ona *et al.*, 2017). Cashew nut is a resilient, drought-tolerant tree that grows well in regions receiving 50 to 350 cm of annual rainfall (Ona *et al.*, 2017), can survive in extremely high temperatures and can adapt to soils with low nutrient levels (Ramteke *et al.*, 2020). In Bangladesh, cashew locally known as Kajubadam, is an economically promising fruit that gaining popularity because of its tasty and highly nutritious seed (kernel), which is extracted by shelling of roasted fruits (Amar Singh, 1992). Cashew kernels are highly nutritious, containing protein (21%), fat (47%), carbohydrates (22%), and essential minerals like phosphorus (0.45%) and calcium (0.55%).

They are also rich in vitamins such as B-1 and riboflavin and considered a safe food due to their unsaturated fatty acids (Mangal, 2016). Cashew kernels are used in snacks, desserts, and cooking, including dishes like Payes, Faluda, and chocolates. They can substitute almonds or peanut butter and are heart-friendly, containing 77% unsaturated fats and less fat than many other nuts (Ona *et al.*, 2017). The cashew apple is a nutritious, fragrant, juicy, pear-shaped fruit and rich in vitamin C (about 5 times higher than the orange). It's used to make juice, wine, jams, pickles, and chutneys. Cashew nut shell liquid (CSNL), a by-product of cashew nuts, is also considered a valuable raw material which is widely used in paints, textiles, resins, ship-building and varnish industries (Sethi *et al.*, 2015).

Cashew nut cultivation in Bangladesh began approximately 30 to 35 years ago, primarily in the Chittagong and Chittagong Hill Tracts regions. It is also grown to a limited extent of 16 other districts (Sohel, 2021). In Bangladesh, cashew nut production increased to 1,462 tonnes in the fiscal year 2020–21, from 1,323 tonnes in 2019–20 (Sohel, 2021). According to the Ministry of Agriculture of Bangladesh, around 5 lakh hectares of land remain uncultivated in the three hill districts of Rangamati, Khagrachhari, and Bandarban (Ali, 2021). Due to its rich nutritional content and growing consumer affordability, the demand for cashew is rising both globally and locally. To meet market demands, it is essential to identify and cultivate superior, high-yielding and efficient cashew nut varieties. Therefore, the present study aimed to identify the high-yielding cashew germplasm suitable for commercial cultivation in the north-eastern hilly region of Bangladesh.

MATERIALS AND METHODS

The experiment was conducted at Citrus Research Station, Bangladesh Agricultural Research Institute, Jaintapur, Sylhet during 2024-25. The experiment comprised of five germplasm, i.e, AO Jai-001, AO Jai-002, AO Jai-003, AO Jai-004 and AO Jai-005 collected from different areas of Bangladesh. The plants were planted during the year 2019 at a spacing of 6mx6m using Randomized Block Design (RBD) with four plants treatment^{-1} replicated three times. The experimental site is located at 36 m above sea level, with coordinates of 25°13562' N latitude and 92°13217' E longitude. The average annual rainfall is 3500-6000 mm, with more than 80% of it falling between June and July. The soil at the experimental site was a sandy loam texture soil with a pH of 4.8, and 1.28% organic carbon. A common application of manures and fertilizers i.e. 10kg cow dung, 250g urea, 250g TSP, 200g MoP, 70g gypsum, 20g zinc sulphate and 10g boric acid per tree were applied in two equal splits, i.e. first in the first fortnight of June and second in the first fortnight of October. Data on tree growth as well as quantitative characteristics were recorded as per 'Descriptors for Cashew' published by IBPGR in (1986). Plant volume was calculated by using the formula of Castle (1983). Tree Volume = $\frac{1}{6}\pi$ × plant height × $(2r)^2$, where 2r = (East-West spread + North-South spread)/2. Data were analyzed statistically using MSTAT-C program. Mean was calculated and analysis of variance for each of the characters was performed by F test (Variance Ratio). Difference between treatments was evaluated by

Duncan's Multiple Range (DMRT) test at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The experimental results obtained from the present investigation have been described under the following heads:

Vegetative growth characteristics

Cashew germplasm differed significantly in terms of growth characteristics (Table 1). The five cashew germplasms exhibited three distinct plant habits: AO Jai-003 showed an upright and open growth form, AO Jai-005 had a spreading habit, while the remaining germplasms displayed an upright and compact structure. There were no significant differences in plant height among the germplasms, with the tallest plant observed in AO Jai-001 (5.74 m) and the shortest in AO Jai-004 (5.14 m). For base girth, AO Jai-001 recorded the highest value (62.23 cm), followed by AO Jai-002 (54.66 cm) and AO Jai-003 (53.32 cm), whereas AO Jai-004 (52.06 cm) and AO Jai-005 (49.88 cm) had the smallest girths. In cashew cultivation, the plant volume is a critical factor as it reflects the fruit-bearing area and influences both tree spacing and planting density per unit area. In terms of plant volume, AO Jai-001 had the largest (75.08 m^3), while AO Jai-002 (52.18 m^3) and AO Jai-004 (47.68 m^3) had the smallest volumes. The widest canopy spread, both north-south and east-west, was also noted in AO Jai-001 (4.83 m and 5.23 m, respectively), whereas AO Jai-004 had the narrowest spread (3.57 m × 4.47 m). Ona *et al.* (2017) also observed that cashew varieties like AO Hat-002 and AO Hat-003 exhibited shorter and less spreading growth habits in Chittagong and Chittagong hill tracts area. Variations in growth parameters such as plant height, base girth, and canopy spread among different cashew varieties and hybrids have also been documented by Ona *et al.* (2017).

Table 1. Growth characteristics of cashew nut germplasm

Germplasm	Plant habit	Plant height (m)	Base girth (cm)	Plant volume (m^3)	Canopy spread (m)	
					N-S	E-W
AO Jai-001	Upright and compact	5.74	62.23a	75.08a	4.83a	5.23a
AO Jai-002	Upright and compact	5.69	54.66ab	52.18c	4.1b	4.43c
AO Jai-003	Upright and open	5.39	53.32ab	67.19b	4.7a	4.9b
AO Jai-004	Upright and compact	5.14	52.06b	47.68c	3.57c	4.47c
AO Jai-005	Spreading	5.29	49.88b	62.91b	4.8a	4.33c
LSD $_{(0.05)}$		NS	9.36	7.59	0.38	0.19
CV%		9.26	9.13	6.61	4.58	2.21

Ona *et al.* (2017), Naik *et al.* (1997), Swamy *et al.* (2000), Dorajeerao *et al.* (2002), and Reddy *et al.* (2002a). The growth pattern of any perennial tree plays a crucial role in shaping its overall structure. According to Mangal (2016), growth rate and canopy expansion significantly impact pruning strategies, particularly in high-density plantations or under low soil fertility conditions, where even tall and vigorous varieties can be adapted for closer spacing.

Flower characteristics

Flower initiation in cashew is a critical phenological event influenced by various factors such as genotype, environmental conditions, and cultural practices. Flower initiation in cashew occurred from first week to third week of February. Data presented in (Table 2&3) showed the variation in different varieties with respect to flower Initiation, where AO Jai-003 was the earliest (25.01.25) and AO Jai-004 was the latest flowering (22.02.25). Ona *et al.* (2017) reported that the flowering season in cashew ranged from January to February. Similar variations in flowering time were noted by Bhaskara Rao (1998), Reddy *et al.* (2002b) and Desai *et al.* (2001) at different locations. Desai *et al.* (2010) also identified Vengurla-4 as an early-bearing hybrid variety. According to Mangal (2016), early flowering (Nov–Dec) was observed in six cashew genotypes: 3/33, 30/1, VRI-1, H-320, H-303, and NRCC Sel-2, while late flowering (Jan–Feb) was seen in 3/28 and NRCC Sel-1. The timing of flowering varies across regions, influenced by factors such as altitude, temperature, humidity, and rainfall.

Table 2. Flower characteristics of cashew nut germplasm

Germplasm	Flower initiation	Shape of inflorescence	Compactness of inflorescence	Position of inflorescence	Color of inflorescence	Days to 50% flowering	Days to 100% flowering
AO Jai-001	18.02.25	Broadly pyramidal	Loose	Terminal	Pink	33.13ab	48.88ab
AO Jai-002	09.02.25	Broadly pyramidal	Loose	Terminal	Cream	36.25ab	48.50ab
AO Jai-003	25.01.25	Pyramidal	Loose	Terminal	Pink	29.63b	42.38b
AO Jai-004	22.02.25	Narrowly pyramidal	Loose	Terminal	Pink	35.75ab	47.25ab
AO Jai-005	17.02.25	Narrowly pyramidal	Loose	Terminal	Cream	40.38a	54.13a
LSD (0.05)						7.34	11.99
CV%						11.16	13.25

Table 3. Flower characteristics of cashew nut germplasm

Germplasm	Hermaphrodite flowers/panicles	Male flowers/ panicles	Sex ratio	Days to harvesting (Fruit formation)
AO Jai-001	107.33a	464.67a	0.23b	46.33bc
AO Jai-002	69.00c	268d	0.26a	50.67abc
AO Jai-003	95.67b	360b	0.27a	42.67c
AO Jai-004	30.33e	186.67e	0.16c	55.67a
AO Jai-005	52.00d	287.33c	0.18c	53.67ab
LSD (0.05)	6.65	11.95	0.03	8.36
CV%	4.99	2.03	6.38	8.92

The inflorescence shapes of all the studied germplasm were broadly Pyramidal in 2 germplasm (AO Jai-001 and AO Jai-002), pyramidal in AO Jai-003 and narrowly pyramidal in 2 remaining germplasm (AO Jai-004 and AO Jai-005). Generally, the germplasm with broadly pyramidal inflorescence shape had higher width compared to length. Ona *et al.* (2017) also reported that the shape of inflorescence either 'Narrowly Pyramidal' in 3 germplasm, Pyramidal' in 3 germplasm and 'Broadly Pyramidal' in the remaining 2 genotypes among 8 germplasm. Mangal (2016) observed three types of inflorescence in 14 cashew genotypes and Sena *et al.* (1995) also reported two types of inflorescence in 17 cashew cultivars.

All the cashew germplasm exhibited a loose inflorescence pattern in relation to their growth behavior.

A similar observation was reported by Ona *et al.* (2017) in eight cashew germplasm lines and by Mangal (2016) in fourteen cashew genotypes. The inflorescence positions of the cashew germplasm were terminal. Similar findings were noted by Mangal (2016) in fourteen different cashew genotypes.

With regard to the inflorescence color, among the five cashew germplasm, three (AO Jai-001, AO Jai-003, and AO Jai-004) produced pink flowers, while only two (AO Jai-002 and AO Jai-005) exhibited cream-colored flowers. Similar findings were found by Ona *et al.* (2017) in eight cashew germplasm. Mangal (2016) reported that most cashew genotypes (12) typically had pink flowers, while only two genotypes exhibited cream-colored flowers.

According to Weevers (1952), the flower color in cashews may develop or change during the anthesis period.

A notable variation was observed in the number of days required to reach 50% and 100% flowering among the five cashew germplasm. AO Jai-003 recorded the shortest flowering duration, with 29.63 days for 50% and 42.38 days for full flowering. In contrast, AO Jai-005 required the longest period, taking 40.38 days for 50% and 54.13 days for 100% flowering, indicating a prolonged flowering phase. The findings align with those of Hanumanthappa *et al.* (2014), who reported that Ullal-1 required the highest number of days (49.36) for full flower emergence, while Vengurla-4 showed the shortest duration, taking only 43.30 days to reach 100%

flowering. AO Jai-001 recorded the highest number of hermaphrodite (bisexual) flowers per panicle (107.33), followed by AO Jai-003 (95.67), while the lowest was observed in AO Jai-005 (52).

The maximum number of male flowers per panicle was also found in AO Jai-001 (464.67), with the lowest in AO Jai-004 (186.67). The highest sex ratio was noted in AO Jai-003 (0.27), closely followed by AO Jai-002 (0.26), whereas AO Jai-004 (0.16) and AO Jai-005 (0.18) showed the lowest ratios. These variations in flower types and sex ratios have also been reported by previous researchers such as Meera and Jayaprakash (2015), Sharma *et al.* (2009), and Singh *et al.* (2008). Since male flowers are predominant in the inflorescence, significant variation in flower count and fruit set per panicle is expected. A higher number of hermaphrodite flowers per panicle generally lead to greater fruit set.

A significant difference was observed in the number of days required for fruit maturity among the various cashew germplasm. AO Jai-004 took the longest time to produce mature fruits (55.67 days), while AO Jai-003 required the shortest duration (42.67 days). Similar variations were also reported by Ona *et al.* (2017) in 8 germplasm.

Yield and yield contributing characteristics

Nuts are the economically valuable part of the cashew tree. Nut and kernel traits are key yield-related factors, and the overall performance or superiority of a variety or genotype is largely determined by these attributes. In this study, variations in nut weight, kernel weight, and their linear dimensions were examined across 5 different cashew germplasm (Table 3).

The highest number of nuts per panicle was recorded in AO Jai-001 (6.27), followed by AO Jai-003 (5.6), while the lowest was observed in AO Jai-005 (2.72). In cashew, not all pollinated hermaphrodite flowers develop into mature fruits, as fruit drop is a common occurrence. This drop is primarily due to physiological factors, with insect attacks also contributing significantly to the loss of immature fruits. According to Solanki *et al.* (2015), environmental factors such as weather and climate can influence fruit retention, leading to variation in cultivar performance under different conditions. Varieties with a higher number of hermaphrodite flowers per inflorescence generally produced more nuts per panicle. Similar variations in nuts per panicle have also been reported by Vikram *et al.* (2013), Poduval (2015), and Hanumanthappa *et al.* (2014).

As per IBPGR (1986), among the five cashew germplasm, only one (AO Jai-005) was placed in the low nut weight category (<5 g), while AO Jai-001 was in the high nut weight category (>7 g). The remaining three germplasm were classified under the intermediate nut weight category (5-7 g). Among these, AO Jai-001 recorded the highest nut weight (7.39 g), while AO Jai-005 had the lowest nut weight (4.81g). Similar observations on nut weight have also been made by Ona *et al.* (2017), Vikram *et al.* (2013), Poduval (2015), and Hanumanthappa *et al.* (2014). The maximum nut size was found in AO Jai-001(3×2.10cm) followed by AO Jai-003 (3×2.07cm) while minimum (2.23×1.60cm) in AO Jai-005.

The highest nut yield per plant was observed in AO Jai-001 (3.52 kg), followed by AO Jai-003 (3.22 kg), while the lowest nut yield per plant (1.50 kg) was recorded in AO Jai-004. Similar variability in nut yield across different germplasm has been reported by Ona *et al.* (2017), Lenka *et al.* (1997), Naik *et al.* (1997), Bhaskara Rao (1998), Sundararaju *et al.* (2006), and Sreenivas *et al.* (2016).

The kernel of the cashew nut is the edible, economically valuable, and processed portion.

Data presented in Table 4 revealed significant variation among the five germplasm in terms of individual kernel weight, size, and total kernel weight per plant. The highest individual kernel weight was observed in AO Jai-001 (2.66 g), followed by AO Jai-003 (2.59 g), while the lowest was recorded in AO Jai-004 (1.24 g). In terms of kernel size, AO Jai-003 had the largest dimensions

(2.84 × 1.76 cm), followed by AO Jai-001 (2.44 × 1.53 cm). The highest edible kernel yield per plant was recorded in AO Jai-001 (1.09 kg), with AO Jai-003 following closely (0.91 kg). The lowest kernel yield per plant was found in AO Jai-004 (0.57 kg). Similar variability in kernel characteristics was also reported by Ona *et al.* (2017) in eight germplasm, Mangal (2016) in fourteen genotypes, Sreenivas *et al.* (2016) in nine F_1 cashew hybrids, and Swamy *et al.* (2000) in sixty-three germplasm accessions.

Table 4. Yield and yield contributing characteristics of different cashew nut germplasm

Germplasm	Nuts/panicle (No.)	Nut weight (g)	Nut size (cm)		Nut yield /plant (kg)	Kernel weight (g)	Kernel size (cm)		Kernel yield /plant (kg)
			Length	Width			Length	Width	
AO Jai-001	6.27a	7.39a	3.0a	2.07	3.52a	2.66a	2.44ab	1.53a	1.09a
AO Jai-002	4.49b	5.66c	2.4b	1.63	2.47b	1.53c	2.24b	0.92b	0.57c
AO Jai-003	5.68a	6.54b	3.0a	2.10	3.22a	2.59a	2.84a	1.76a	0.91ab
AO Jai-004	3.59c	5.54c	2.23b	1.67	1.50c	1.24d	2.25b	0.65bc	0.65bc
AO Jai-005	2.72d	4.81d	2.23b	1.60	2.60b	2.13b	2.52ab	0.56c	0.84abc
LSD $_{(0.05)}$	0.75	0.53	0.54	NS	0.61	0.24	0.41	0.30	0.32
CV%	8.74	4.74	11.26	14.98	12.19	6.19	8.88	14.81	21.27

Table 5. Apple characteristics of cashew nut germplasm

Germplasm	Apple weight (g)	Apple nut size (cm)		Apple TSS (%)	Apple color	Apple yield /Plant (kg)
		Length	Width			
AO Jai-001	63.67a	5.75a	4.3ab	13.5a	Light Red	11.37a
AO Jai-002	45.67bc	4.97ab	3.8bc	10.7c	Yellowish red	8.36b
AO Jai-003	50.67abc	5.87a	4.4a	11.9b	Yellow	11.38a
AO Jai-004	54.33ab	4.1b	3.7c	10.6c	Yellowish green	6.78c
AO Jai-005	38.67c	4.1b	3.9abc	10.8bc	Yellowish red	8.60b
LSD $_{(0.05)}$	14.51	0.98	0.57	1.12	-	1.56
CV%	15.23	10.50	7.52	5.19	-	9.01

Apple characteristics

In addition to cashew nuts, cashew apples are also a valuable economic product. However, their potential remains largely underutilized, Given that cashew apple yield is also important to cashew growers alongside nut yield, the size and yield of apples must be considered when developing high-yielding, improved cashew varieties.

According to the cashew descriptor list provided by IBPGR (1986), apple weights ranging from 36 to 43g are classified as 'intermediate', those below 36g are considered 'low', and weights exceeding 43g fall into the 'high' category. Table 5 showed that AO Jai-001, AO Jai-002, AO Jai-003 and AO Jai- 004 were in 'high' class and AO Jai- 005 was in 'intermediate' class. Bhaskara Rao (1998) also documented a broad range in cashew apple weight, varying from 30 to 150 g. A significant variation was observed with respect to apple size, where the highest apple size was recorded in AO Jai-003 (5.87×4.4 cm) followed by AO Jai-001 (5.75×4.3 cm) and lowest in AO Jai-004 (4.1×3.7 cm). Significant differences in apple size and weight were similarly reported by Swamy *et al.* (2000) in Karnataka and Reddy *et al.* (2002b) in Andhra Pradesh.

Significant variation in Total Soluble Solids (TSS%) was observed among the five germplasm studied (Table 5). The highest TSS was recorded in AO Jai-001 (13.5%), followed by AO Jai-003 (11.9%), with the remaining germplasm showing lower values. Similar findings were reported by Ona *et al.* (2017), who observed TSS values ranging from 8.1% to 14% across eight germplasm, and by Mangal (2016), who recorded a TSS range of 11.25% to 15.16% among 14 cashew genotypes. The color of the cashew apple ranged from yellow to red (Table 5). Dorajeerao *et al.* (2002) reported that apple color varied between yellow and yellow-red among fourteen cashew clones. Similarly, Mangal (2016) observed yellow apples in ten genotypes and red apples in four genotypes. The highest apple yield per plant was recorded in AO Jai-003 (11.38 kg), followed by AO Jai-001 (11.37 kg), while the lowest yield was observed in AO Jai-004 (6.78 kg).

CONCLUSION

All cashew nut germplasm exhibited significant differences in growth, flowering, yield, and fruit attributes evaluated. AO Jai-001 exhibited superior vegetative growth with the tallest height (5.4 m), highest base girth (62.23 cm), and maximum plant volume (75.08 m^3), along with the widest canopy spread. Significant differences in inflorescence types, flowering duration, sex ratio, and fruit maturity periods were observed, with AO Jai-003 showing the early flowering (25.01.25) and maturity durations (42.67 days), potentially offering early harvest advantages. On the other hand, AO Jai-001 also demonstrated strong performance on highest nut weight (7.39 g), nut yield (3.52 kg/plant), kernel weight (2.66 g), and kernel yield (1.09 kg/plant), classifying it as a high-performing variety. In contrast, AO Jai-005 showed the lowest productivity in terms of nut yield, kernel weight, and nut size, placing it in the low-yielding category. For cashew apples, AO Jai-003 and AO Jai-001 had the largest apple sizes and highest TSS (11.9% and 13.5%, respectively), placing them in the 'high' quality class, while AO Jai-005 was in the 'intermediate' category. Variations in apple traits, including size, weight, color, and TSS%, further highlighted the importance of genotype selection for dual-purpose (nut and apple) utilization. Overall, the evaluation of five cashew germplasm indicated that AO Jai-001 and AO Jai-003 were promising for their vigorous growth, desirable flowering patterns, high yields of both nuts and apples, and superior fruit quality. Therefore, these two germplasm are well-suited for commercial cultivation in the north-eastern hilly regions of Bangladesh. The results highlight the importance of assessing genetic diversity in cashew to boost productivity and fulfill market requirements.

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