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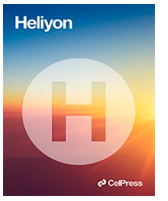

Research article

Participatory variety evaluation and selection of chickpea (*Cicer arietinum* L.) varieties; an underpinning to novel technology uptake in northwestern Ethiopia

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ABSTRACT

The productivity and production of chickpeas can be improved by using access-improved varieties that are suitable for the specific agroecology. However, the foundation for adopting new technology is participatory variety selection (PVS). Therefore, this study aimed to identify the best adaptively improved chickpea varieties in northwestern Ethiopia based on the preferences of farmers in Adet and Fogera Districts. The experiment consisted of ten improved chickpea varieties (Desi and Kabuli) that were evaluated in three replications using the mother baby trail approach, including on-station and on-farm evaluations. According to this trail, the highest grain yield among different types of chickpeas was observed in the varieties Teketay (2327.8 kg/ha), Dalota (2175.9 kg/ha), and Geletu (2123.6 kg/ha). Among the Kabuli types, Koka (2813.2 kg/ha) and Dhera (2325.7 kg/ha) showed the highest mean values of grain yield. At Adet location, the varieties Teketay (2772.2 kg/ha), Dalota (2459.7 kg/ha), and Geletu (2270.8 kg/ha) produced the highest grain yield. Similarly, Koka (3195.8 kg/ha), Dhera (2604.2 kg/ha), and Ejere (2601.4 kg/ha) were the top-yielding Kabuli chickpea varieties. Farmers from Adet location in Senkengha Kebele selected three Desi and three Kabuli chickpea varieties, namely Geletu, Teketay, and Dalota, in that order, as well as Koka, Hora, and Ejere. Meanwhile, farmers in Mousobo Kebele identified Koka, Dhera, and Hora from the Kabuli type as the best varieties. The varieties Geletu (1976.4 kg/ha), Dalota (1891.9 kg/ha), and Teketay (1883.3 kg/ha) had the highest mean grain yield at Fogera location. Similarly, in the Kabuli chickpea varieties, the highest mean value of grain yield was obtained from Koka (2430.6 kg/ha) followed by Hora (2097.2 kg/ha), and Dhera (2047.2 kg/ha). Farmers have chosen three of the best Desi and Kabuli chickpea varieties, i.e Geletu, Teketay, and Dalota, and Local check (Shasho) followed by Koka and Ejere at Fogera location, Geina Kebele in that order. In conclusion, the adoption and dissemination of new improved varieties for the new environment can assist the producers such as the farmers for effective chickpea production. This leads to sustainable self-sufficiency of food at the household and country level.

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1. Introduction

The crop chickpea (*Cicer arietinum* L.) is a self-pollinated, annual diploid (2n = 2x = 16) species. It is considered the third most important grain legume in the world after dry beans and field peas [1,2]. Two types of chickpeas differ in their geographical spreading and plant type mainly the Kabuli (Macrosperma) and Desi (microsperma). The Desi types of chickpea are small angular seeds that can weigh about 120 mg, wrinkled at the beak, and range in color from brown to light brown and fawn. Desi types are normally earlier maturing and optimum yielder than the Kabuli. Kabuli types weighing about 400 mg are white cream in color and appearance than the Desi chickpea varieties [3]. India is the largest chickpea producing country accounting for 72 % of the global chickpea production. The other major chickpea producing countries include Australia (6 %), Pakistan (5 %), Turkey and Myanmar (4 %), Ethiopia (3.5 %), Iran and Mexico (2 %), Tanzania (1 %), andMalawi (0.5 %). Ethiopia is the largest producer, consumer, and exporter of chickpeas in Africa and shares more than 60 % of Africa's global chickpea market [2]. Even though the yield of Desi chickpeas in Ethiopia decreased by 0.4 % from 21.2 in 2019/20 to 21.1 q/ha in 2020/21 [4,5]. The regional yield of Desi was reduced by 1.7 % while in Oromia it was reduced by 4 %. Whereas Kabuli chickpeas showed, significant improvement in yield in Oromia between the two years [4,5]. The yield advantage of improved chickpea varieties is up to fourfold more than farmers's local varieties [1]. Many improved chickpea varieties have been released in Ethiopia. However, farmers have no ample and sufficient information about the released varieties because they were released with less involvement of farmers and other stakeholders [6]. According to Tarekegne et al. [7] in any food crop, improved varieties should be tested for their adaptation to a specific agro ecologies and made available to farmers as soon as possible to reduce the yield gap caused by lack/poor access because participatory variety selection and evaluation addresses problems of farmers that were not touched by the formal breeding system [8]. Therefore, Participatory varietyselection has an important role in adaptation and broadcasting of varieties in short period of timethan centralized approach [7]. Adet and Fogera districts are among very suitable geographies for the production of chickpeas. Yet, the productions of the crop in the districts are limited in a few kebeles with low production and productivity due to lack of improved varieties. Thus, this study was carried out with the following objectives (1) selecting highly adaptive and performing improved chickpea varieties through participatory variety selection and (2) identify farmers' selection criteria and perception for future chickpea genetic improvement in the study areas.

2. Materials and methods

2.1. Study areas and climatic description during the experimental period

The trial was carried out during the main cropping season from October to February 2022/2023 in two districts, Adet and Fogera, in Northwestern Ethiopia (Table 1)

Monthly, the maximum and minimum temperature in degrees Celsius, rainfall in millimeters, and relative humidity in percent were recorded at various testing locations throughout the plant growth period (Fig. 1). The highest amount of rainfall was recorded in September at all testing locations, with Adet station recording between 200 and 250 mm and Fogera recording between 50 and 230 mm. Additionally, the maximum amount of temperature was recorded from December to March in all testing locations.

2.2. Experimental materials

Ten released chickpea varieties (Desi and Kabuli) were tested in the trial and the varieties were obtained from Debre Zeit agricultural research centers (Fig. 2, Table 2).

2.3. Experimental design and fieldwork

The experiment was conducted following the guidelines developed by Assefa et al. [10] for a mother and baby trial fashion. The mother trial was a researcher-managed trial conducted at a research site or farmer training center with a well designed and replicated trial. The layout was a Randomized Complete Block Design (RCBD) with three replications at Adet Agricultural Research Center and Fogera National Rice Research Institution. Each plot size was 1.5 m × 2 m (3 m^2), with a spacing of 0.1 m between plants and 0.4 m between rows. Four rows of plants were used in each plot, two of which were used in the middle for data collection while the outer ones served as border rows. The plots and blocks were 0.5 m and 1.5 m apart respectively.

The baby trial, on the other hand, was conducted jointly by farmers, extension workers, and researchers, and only in farmers' fields. This trial involved farmers in the process of variety evaluation and selection. Each selected kebeles at Yilmana Densa and Fogera

Table 1
Detail descriptions of the experimental sites.

Location	Altitude (m.a.s.l)	Soil type	Average Rain fall (mm)	Temperature		Global reference	
				Min (C^0)	Max (C^0)	Latitude	Longitude
Adet	2240	Nitisol	1284	16.8 °C	23.5 °C	11°17′N	37°43′E
Fogera	1810	Pellic Vertisol	1292.6	13.0 °C	26.7 °C	11°58′N	37°41′E

M.a.s.l = Meter above sea level, mm = millimeters, Min = Minimum, Max = maximum temperature.

Districts had a plot size of 5 m × 5 m (25 m^2). Each plot contained 12 rows with between-row spacing of 0.4 m and between plants of 0.1 m. Additionally, there was a gap of 0.8 m between plots.

2.4. Data collection in the mother trial

2.4.1. Phenological parameters

Days to 50 % flowering (DF): It was record as the number of days from planting to 50 % of the plants produce flower per plot through visual observation.

Days to 90 % Physiological maturity (DPM): As the number of days from planting to when 90 % of the plants shown yellowing pods and leaves through visual observation.

2.4.2. Growth parameters

Seedling stand count (STC): The total numbers of seedlings per plot were recorded in an early stage of plant growth.

Number of primary branches (NPB): It was determined by counting the primary branches of five randomly selected plants with in the net plot area.

Number of secondary branches (NSB): It was determined by counting of secondary branches from the primary branches by selecting five plants randomly with in the net plot area.

Plant height (PH): The average height in centimeters of five randomly selected plants in the net plot area was recorded from the soil surface to the top of the canopy of the plant.

Plant count at harvest (PCH): The total number of plants in the net plot area at harvest maturity.

2.4.3. Yield and yield related traits

Number of pods per plant (NPP): The number of pods in a plant was determined by selecting of five plants randomly with in the net plot area.

Number of seeds per pod (NSP): The number of seeds per pod was determined by selecting five pods randomly followed by five plants, which were previously tagged.

Biomass yield (BM): Biomass yield was recorded from a net plot area-using total above ground biomass at harvest maturity.

Grain Yield (GY): It was determined after harvesting all plants from each net plot area, threshing it and separating the straw from the grain and weigh in kilogram after adjusting the grain moisture content into 11 % and it was change to per hectare basis.

Hundred Seed Weight (HSW): It was measured by counting hundred seeds from each variety and measuring each in sensitive balance in gram.

Harvest Index (HI): It was determined by dividing weight of actual yield (grain yield) for total biomass weight and multiply by hundred.

$$HI = \frac{\text{Grain yield(Kg/ha)} \ \text{X} \ 100\%}{\text{biomass yield(Kg/ha)}}$$

2.5. Farmers participatory variety evaluation and selection

The participatory variety evaluation and selection process was conducted using a pairwise and direct matrix ranking based on the

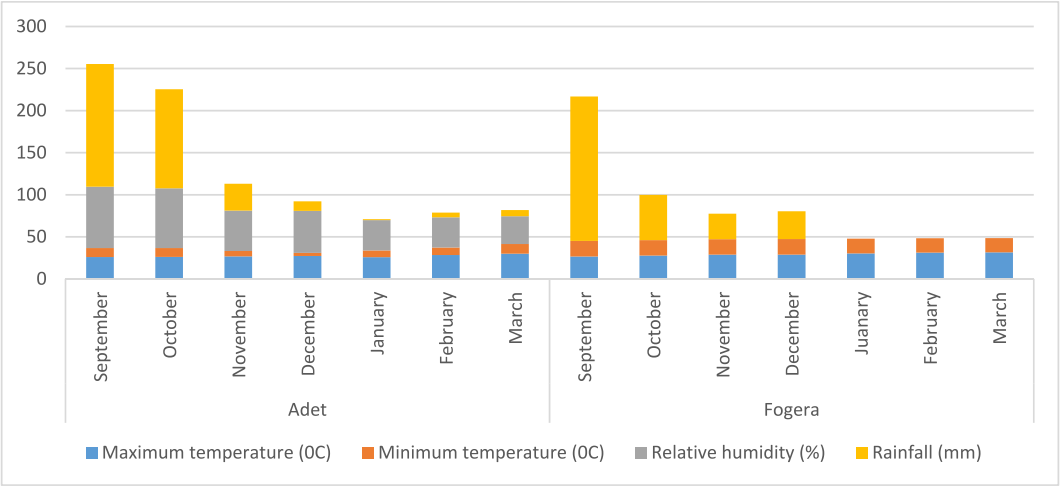

Fig. 1. Weather and Climatic conditions during 2022/23cropping season.

guideline developed by Boef and Thijss [11] as follows.

2.5.1. Pair wise ranking and procedures

When conducting a comparison between different varieties, it is crucial for the facilitators to keep a record of the reasons behind their choice. This process, known as participatory varietal selection, often involves ranking tools to make decisions about which varieties to proceed with in the selection and evaluation process. The following are the prescribed procedures for this process. Step 1: Selection criteria's can be ranked pair-wise in a table both in horizontally in the rows and vertically in the columns.

Step 2: every time a participant or the group has to decide, which selection criteria has preference over the other.
Step 3: The informal discussion leading to the decision should be well recorded as qualitative information.

2.5.2. Matrix ranking and procedures

Matrix ranking is a method to compare and analyze a range of varieties in both qualitative and quantitative ways. It can be used to compare local varieties, or to compare them with introduced or tested varieties. This method shows how farmers evaluate the varieties they use. It is commonly used in participatory varietal selection and participatory plant breeding, just like other ranking methods. Additionally, matrix ranking is useful for comparing and assessing other resources, issues, and ideas. The following procedures are usually followed when using this method.

Step 1. Make a matrix with the criteria in the first column; criteria have been identified through brainstorming or through simple ranking. Put the varieties in the first row (use cards or symbols).

Step 2. Let participants rank the varieties for each character.

Step 3. A weighed ranking of varieties can be calculated as the product of the value for the criteria and the score for each specific variety. In that way, all varieties can be compared with each other.

2.6. Data analysis

2.6.1. Linear mixed model

The Analysis of variance (ANOVA) of all parameters and measurements was done using linear mixed model of SAS Software version 9.4 represented by the following equation;

$$\mathrm{Yijr} = M + \mathrm{Gi} + \mathrm{Lj} + \mathrm{Br(Lj)} + GiLj + Eijr$$

where: Yijr = the observed variable response of the genotype i in the location j and block r, M = grand mean, G = genotype, L = location, B = block effects and Eijr = random error; while the LSD testat 5 % and 1 % level of significance was made using R software version 4.2 (metan and agricolae Packages). A pair wise ranking and direct matrix methods were used to examine the data acquired

Fig. 2. Improved Desi and Kabuli chickpea varieties used for the PVS experiment.

with the farmers' participation during the variety evaluation and selection process.

3. Results

3.1. Disease response of the evaluated improved chickpea varieties

At Adet location, a series of Fusarium wilt incidences were observed between the final vegetative and crop maturity stages. The disease was scored twice using a 1 to 9 descriptive scale. At Fogera station, collar rot was observed at the early seedling stage in addition to Fusarium wilt. Each disease was scored twice using the same descriptive scale. The incidence was calculated using the following formula.

$$\text{Incidence } (\%) = \frac{\text{Dead seedlings/infected plant}}{\text{Total (dead + health)}} x100$$

At Adet location, the highest incidence of Fusarium wilt was recorded in the Local check (13.5 %), followed by Geletu (7.0 %). The lowest disease incidence was recorded in the varieties Eshete (2.8 %) and Dalota (2.7 %) among the Desi chickpea varieties. Among the Kabuli chickpea varieties, the variety Ejere (6.8 %) followed by Shasho (4.2 %) were the most susceptible varieties, while the varieties Dhera (1.7 %) and Koka (2.5 %) were the most resistant varieties. Furthermore, the highest mean incidence of collar rot was recorded in the variety Geletu (3.5 %), and the least incidence was recorded in the variety Eshete (1.5 %) among the Desi chickpea varieties. The variety Ejere (6.5 %) had the highest mean value of collar rot disease incidence, while the lowest was recorded in the local check/Shasho (0.7 %) among the Kabuli type chickpea varieties. On the other hand, in the Desi type chickpea varieties, the local check (5.5 %) followed by the variety Geletu (4.8 %) had the highest incidence, while the lowest was recorded in the variety Teketay (2.8 %). Furthermore, the highest incidence of Fusarium wilt was observed in the local check/Shasho (5.7 %), while the variety Dhera (2.0 %) was the most resistant variety among the Kabuli chickpea varieties at Fogera location.

3.2. Combined analysis of variance over location

There were significant differences in various parameters including days to 50 % flowering (DF), days to 90 % physiological maturity (DPM), number of pods per plant (NPP), number of seeds per pod (NSP), plant height (PH), plant count at harvest (PCH), grain yield (GY), biomass yield (BMY), hundred seed weight (HSW) and harvest index (HI) due to the main effect of varieties (Table 3). Similar results were reported by Goa et al. [8]. The main effect of locations also had a significant effect on DF, DPM, NPP, PH, PCH, GY, and BMY, while NSP was significantly affected. The interaction of varieties with locations highly influenced DF, PH, PCH, while DPM, GY, and BMY were significantly affected in the Desi chickpea varieties (Table 3). In the Kabuli chickpea varieties, there were highly significant differences in seedling stand count (STC), plant count at harvest (PCH), and a significant effect on GY due to the interaction of varieties with locations. This could be due to the genetic potential of the varieties and their interaction with biotic and abiotic components of the environment. Gene expression needs specific and favorable conditions for the traits under consideration. The main effect of varieties also highly influenced STC, PH, PCH, GY, and HSW. DF, DPM, and BMY were also significantly affected. Apart from this, the main effect of locations had a highly significant and significant effect on STC, DF, PCH, GY, BMY, and PH. Shumi et al. [12] also observed the presence of a significant difference among the varieties on NPP, HSW and GY at three locations (Table 3).

3.3. Mean performance of varieties in individual and combined over location

3.3.1. Grain yield

The table below presents the mean values of grain yield obtained from different varieties of Desi and Kabuli chickpea. Among the

Table 2
Detail description of chickpea varieties used.

Desi type				
No	Name of varieties	Origin	Development	Year of release
1	Teketay	ICRISAT	introduction, evaluation and release	2013
2	Dalota	ICRISAT	introduction, evaluation and release	2013
3	Geletu	ICRISAT	introduction, evaluation and release	2019
4	Eshete	ICRISAT	introduction, evaluation and release	2020
5	Local	–	–	–
Kabuli type				
6	Ejere	ICARDA	introduction, evaluation and release	2005
7	Hora	ICARDA	introduction, evaluation and release	2016
8	Dhera	ICARDA	introduction, evaluation and release	2016
9	Koka	ICRISAT	introduction, evaluation and release	2019
10	Local (Shasho)	ICARDA	introduction, evaluation and release	1999

Source: [2], [9].

Table 3
Combined Analysis of Variance (ANOVA) of the mother trail across locations.

Desi type								
Source of variation								
	Rep (Loc.(df = 2)	Var (df = 4)		Loc (df = 1)		Var *Loc (df = 4)		Error (df = 16)
Parameters	Mean sum of square	Mean sum of square	F Value	Mean sum of square	F Value	Mean sum of square	F Value	Mean sum of square
STC	14.933333^{ns}	30.383333^{ns}	3.99	4.033333^{ns}	0.38	7.616667^{ns}	0.72	10.650000
DF	0.833333^{ns}	66.45000[a]	1.75	418.133333[a]	140.6	38.050000[a]	12.8	2.975000
DPM	2.700000^{ns}	546.216667[a]	7.88	410.700000[a]	23.8	69.283333*	4.02	17.250000
NPB	0.100333^{ns}	1.876333^{ns}	1.19	0.176333^{ns}	0.24	1.576333^{ns}	2.19	0.720333
NSB	16.809333^{ns}	18.315333^{ns}	0.24	74.576333^{ns}	2.07	75.721333^{ns}	2.10	36.004333
NPP	1162.065333[a]	1446.42200[a]	5.06	9342.145333[a]	57.8	285.702000^{ns}	1.77	161.624000
NSP	0.065333^{ns}	0.385500[a]	9.14	0.261333*	6.2	0.042167^{ns}	1.00	0.042333
PH (cm)	8.777160^{ns}	293.486047[a]	7.60	1888.450680[a]	314.3	38.630713**	6.43	6.006810
PCH	1.530333^{ns}	46.937000[a]	1.07	76.480333[a]	52.2	43.813667[a]	29.95	1.462833
GY(Kg/ha)	39472^{ns}	1337053[a]	11.42	2428720[a]	120.2	117110**	5.80	20194
BMY(Kg/ha)	107240^{ns}	9616753[a]	12.08	11022656[a]	88.4	796352**	6.39	124695
HI (%)	0.000103^{ns}	0.013797**	2.68	0.000213^{ns}	0.04	0.005147^{ns}	2.16	0.002379
HSW (gm)	3.900000^{ns}	170.466667[a]	13.42	2.70000^{ns}	0.30	12.7000^{ns}	1.43	8.883333
Kabuli type								
Parameters	Rep (Loc.(df = 2)	Var (df = 4)		Loc (df = 1)		Var *Loc (df = 4)		Error (df = 16)
	Mean sum of square	Mean sum of square	F Value	Mean sum of square	F Value	Mean sum of square	F Value	Mean sum of square
STC	0.400000^{ns}	44.283333[a]	2.18	2.700000^{ns}	1.24	20.283333[a]	9.29	2.183333
DF	5.833333*	18.716667**	4.21	572.033333[a]	166.6	4.450000^{ns}	1.30	3.433333
DPM	60.033333^{ns}	342.950000*	5.17	104.533333[a]	6.54	66.283333*	4.15	15.966667
NPB	1.236000^{ns}	0.718000^{ns}	0.78	0.012000^{ns}	0.02	0.915333^{ns}	2.15	0.425667
NSB	5.241333^{ns}	6.708000^{ns}	1.07	0.645333^{ns}	0.14	6.278667^{ns}	1.35	4.645333
NPP	209.977333^{ns}	148.113333^{ns}	0.71	26.885333^{ns}	0.18	209.538667^{ns}	1.47	142.324000
NSP	0.112000^{ns}	0.058000^{ns}	0.64	0.108000^{ns}	1.57	0.091333^{ns}	1.33	0.068667
PH (cm)	37.554280^{ns}	287.877647[a]	23.65	242.650080*	7.36	12.171913^{ns}	0.37	32.979280
PCH	0.433333^{ns}	48.716667[a]	2.51	20.833333[a]	31.3	19.416667[a]	29.12	0.666667
GY(kg/ha)	42634^{ns}	519344[a]	2.61	2354185[a]	40.6	198674*	3.43	57994
BMY(Kg/ha)	179591^{ns}	984188*	1.81	14008333[a]	55.3	542907^{ns}	2.14	253554
HI (%)	0.000280^{ns}	0.004433^{ns}	2.87	0.001080^{ns}	0.71	0.001547^{ns}	1.02	0.001513
HSW (gm)	0.100000^{ns}	55.71667[a]	101.30	4.800000^{ns}	1.78	0.550000^{ns}	0.20	2.683333

Abbreviations: Rep: replication; Loc: location; df: degree of freedom; Var: Variety; STC: seedling stand count; DF: Days of flowering; DPM: Days of physiological maturity; NPB: number of primary branches; NSB: number of secondary branches; NPP: number of pod per plant: NSP: number of seed per pod; PH: plant height; PCH: plant count at harvest; GY: grain yield; HSW: hundred seed weight; BMY: biomass yield and HI: harvest index.
[a] Significant; ns: non-significant.

Desi chickpea varieties, Teketay (2327.8 kg/ha) was found to have the highest grain yield, followed by Dalota (2175.9 kg/ha) and Geletu (2123.6 kg/ha), while the lowest yield was recorded from the Local check (1211.0 kg/ha). Among the Kabuli chickpea varieties, Koka (2813.2 kg/ha) had the highest yield, followed by Dhera (2325.7 kg/ha), and the lowest yield was noted from the variety Hora (2103.5 kg/ha). Similarly, it was reported that Dalota and Habru were the superior yielders overall at three locations, except for Teketay, which was a high yielder on farmer fields. However, the overall means indicated that Dalota (2411 kg/ha) and Habru (1822 kg/ha) were the superior yielders, and they were selected and adopted for cultivation in three districts of Guji Zone of Southern Oromia.

At Adet location, the highest grain yield was obtained from the variety Teketay (2772.2 kg/ha), followed by Dalota (2459.7 kg/ha) and Geletu (2270.8 kg/ha), while the lowest yield was recorded from the Local check (1355.3 kg/ha) in the Desi chickpea varieties. Among the Kabuli chickpea varieties, Koka (3195.8 kg/ha) followed by Dhera (2604.2 kg/ha) and Ejere (2601.4 kg/ha) had the highest yields, and the variety Hora (2109.7 kg/ha) had the lowest yield. Similarly, at Fogera location, the highest mean value of grain yield was obtained from the varieties Geletu (1976.4 kg/ha), followed by Dalota (1891.9 kg/ha) and Teketay (1883.3 kg/ha), while the lowest yield was observed from the Local check (1066.7 kg/ha) among the Desi chickpea varieties. Among the Kabuli chickpea varieties, the highest mean value of grain yield was obtained from the varieties Koka (2430.6 kg/ha), followed by Hora (2097.2 kg/ha) and Dhera (2047.2 kg/ha), while the lowest yield was observed from the variety Ejere (1615.3 kg/ha).

3.3.2. Yield components

In the Desi variety of chickpeas, Dalota had the highest mean plant count at harvest (37.5), followed by Teketay (37.3), and while the Local check, had the lowest (30.7). Among the varieties, Dalota had the highest mean value of number of pods per plant (68.4), followed by Teketay (64.9) and Geletu (63.1). The variety Eshete (1.8) had the highest mean value of seeds per pod. Moreover, Teketay

had the highest biomass yield (BMY) recorded at 5019.5 kg/ha, followed by Geletu at 4876.7 kg/ha and Dalota at 4972.6 kg/ha (Table 6). On the other hand, the Local check had the lowest biomass yield at 2120.0 kg/ha. Similarly, the varieties Geletu, Teketay, and Dalota had the highest mean value of hundred seed weight, with 29.3 g, 27.3 g, and 25.0 g respectively. On the other hand, the variety Eshete recorded the lowest value with 16.7 g, followed by Local check with 19.5 g (Table 6). The variety Koka had the highest mean value of plant count at harvest (PCH), hundred seed weight (HSW), and biomass yield (BMY) in that order, with 38.5, 35.3, and 5902.8 kg/ha. Dhera followed with 36.5, 33.7, and 5555.6 kg/ha respectively. Ejere had the lowest values, with 31.3 for PCH, 29.2 g for HSW, and 4829.7 kg/ha for BMY. However, it had the highest mean number of pods per plant with 56.5, second only to Koka with 61.9 among the Kabuli chickpea varieties. (Table 6).

In Adet location, the variety Teketay showed the highest mean value of plant count and biomass yield at harvest with 38.3 plant count and 5727.8 kg/ha biomass yield, followed by Dalota (37.3) and Local check (36.9) in terms of plant count at harvest, and Geletu (5555.6 kg/ha) followed in biomass yield. Among the Desi type chickpea varieties, Dalota (95.7, 27.0 g) followed by Geletu (80.6, 28.7 g) had the highest number of pods per plant and hundred seed weight, as shown in Table 4. Among the Kabuli type chickpea varieties, Koka exhibited the highest mean values of plant count at harvest, biomass yield, and hundred seed weight, which were recorded at 38.7, 6527.8 kg/ha, and 35.7 g, respectively. The variety Dhera followed with 35.3, 6111.1 kg/ha, and 35.5 g, respectively. The local check had a mean of 36.0 and 6111.1 kg/ha, in plant count at harvest and biomass yield, respectively (Table 4). It appears that the differences in genetic makeup among the varieties might be responsible for the mean variation observed. At Fogera location, the variety Dalota (37.7) had the highest plant count at harvest (PCH), followed by Teketay (36.3, 54.2) and Geletu (35.7). Similarly, in terms of biomass yield, number of pods per plant, and hundred seed weight, Geletu (4389.5 kg/ha, 45.5, 30.0 g) followed by Dalota (4314.5 kg/ha, 41.2, 25 g) were the highest performers, in that order. Furthermore, the variety Teketay (54.2, 27.3 g) was the highest in mean value number of pods per plant (NPP) and hundred seed weight (HSW) among the Desi chickpea varieties (Table 5). Similarly, the variety Koka (38.3, 5277.8 kg/ha, 35.0 g) followed by Dhera (37.7, 5000.0 kg/ha, 33.3 g) were the highest in mean value of plant count harvest, biomass yield and hundred seed weight but also Koka (68.3) followed by Hora (57.5) was the highest in mean value of pod number per plant (Table 5).

3.3.3. Growth parameters

The variety Eshete had the highest combined mean value of seedling stand count, plant height, and number of primary and secondary branches per plant, with measurements of 62.6 cm, 77.7, 4.6, and 14.4, respectively. In addition, the variety Teketay was next with measurements of 51.6 cm, 77.0, 4.8, and 14.8. Meanwhile, the variety Geletu had the highest number of secondary branches per plant, but the shortest plant height, with measurements of 14.7 and 44.8 cm respectively (Table 6). Among the Desi chickpea varieties, the highest mean values of number of primary branches per plant (NPB) and number of secondary branches per plant (NSB) were observed in the Local check (3.9 primary branches, 17.5 secondary branches) while the lowest seedling stand count (STC) was also observed in the same variety (72.2) (Table 6). On the other hand, the variety Koka (75.8) followed by Dhera (72.8) and Local check (72.0) had the highest mean value of seedling stand count (STC). Additionally, the Dhera variety had the highest mean value of both number of primary branches (4.7) and plant height (68.8 cm) while the varieties Hora (16.0) and Koka (15.5, 51.7 cm) had the highest mean value of number of secondary(NSB) but were the shortest among the Kabuli chickpea varieties (Table 6).

In Adet location, the Teketay variety had the highest seedling stand count (STC) of 77.3, followed by Dalota with 76.7 and Eshete

Table 4
Mother trail mean performance of Desi and Kabuli type chickpea varieties at Adet Northwest Ethiopia.

Parameters													
Desi type	STC	DF	DPM	NPB	NSB	NPP	NSP	PH (cm)	PCH	BMY (Kg/ha)	GY (Kg/ha)	HI (%)	HSW (gm)
Teketay	77.3^{a}	60.0^{cd}	119.7^{b}	4.7^{ab}	14.3^{a}	75.5^{a}	1.3^{b}	60.8^{b}	38.3^{a}	5727.8^{a}	2772.2^{a}	0.48^{ab}	27.3^{a}
Dalota	76.7^{a}	63.0^{ab}	125.0^{b}	3.40^{ab}	12.0^{a}	95.7^{a}	1.6^{ab}	50.4^{c}	37.3^{a}	5438.9^{a}	2459.7^{b}	0.45^{b}	27.3^{a}
Geletu	74.7^{a}	62.3^{bc}	121.3^{b}	3.20^{b}	13.9^{a}	80.6^{a}	1.3^{b}	51.7^{c}	35.3^{b}	5555.6^{a}	2270.8^{bc}	0.40^{b}	28.7^{a}
Eshete	76.3^{a}	65.7^{a}	141.0^{a}	5.40^{a}	16.7^{a}	71.9^{ab}	1.9^{a}	73.2^{a}	35.3^{b}	4666.7^{b}	1972.2^{c}	0.42^{b}	16.7^{b}
Local	74.0^{a}	60.0^{d}	126.0^{b}	4.2^{ab}	25.0^{a}	42.0^{b}	1.2^{b}	59.0^{b}	36.9^{ab}	2200.0^{c}	1355.3^{d}	0.58^{a}	22.3^{ab}
CV	4.6	2.4	2.9	26.2	50.8	24.2	14.5	4.2	2.4	5.8	7.5	11.1	15.2
LSD	6.6	2.8	6.9	2.1	15.7	33.4	0.40	4.6	1.7	517.4	305.3	0.097	6.8
Kabuli type													
Ejere	67.7^{c}	61.3^{b}	123.7^{b}	4.1^{a}	14.6^{a}	59.1^{a}	1.4a	55.5^{b}	30.3^{c}	5992.8^{ab}	2601.4b	0.43^{ab}	29.7^{bc}
Hora	68.7^{c}	63.7^{ab}	138.7^{a}	3.9^{a}	16.8^{a}	51.1^{a}	1.1^{a}	55.5^{b}	29.3^{c}	5507.2^{b}	2109.7^{c}	0.39^{b}	32.7^{ab}
Dhera	71.3^{b}	62.0^{b}	141.0^{a}	4.7^{a}	14.1^{a}	51.7^{a}	1.1^{a}	72.7^{a}	35.3^{b}	6111.1^{ab}	2604.2^{b}	0.43^{ab}	34.0^{a}
Koka	77.3^{a}	60.3^{b}	117.0^{b}	3.7^{a}	12.6^{a}	55.5^{a}	1.3a	54.9^{b}	38.7^{a}	6527.8^{a}	3195.8a	0.49^{a}	35.7^{a}
Shasho	73.7^{b}	65.7^{a}	126.3^{b}	4.5	15.6^{a}	60.2^{a}	1.5^{a}	58.6^{b}	36.0^{b}	6111.1^{ab}	2452.8^{bc}	0.40b	28.0^{c}
CV	1.8	2.9	4.0	17.4	16.9	20.8	21.3	11.5	2.0	5.5	9.5	10.6	6.6
LSD	2.4	3.5	9.8	1.4	4.7	21.7	0.51	12.8	1.3	623.7	462.1	0.09	3.9

Abbreviations: LSD: least significant difference; CV: Coefficient of variation, Rep: replication; Loc: location; df: degree of freedom; Var: Variety; STC: seedling stand count; DF: Days of flowering; DPM: Days of physiological maturity; NPB: number of primary branches; NSB: number of secondary branches; NPP: number of pod per plant: NSP: number of seed per pod; PH: plant height; PCH: plant count at harvest; GY: grain yield; HSW: hundred seed weight; BMY: biomass yield and HI: harvest index; ***:significant; ns: non-significant. Means with the same letter in same column are not significantly different and vice versa.

Table 5
Mother trail mean performance of Desi and Kabuli type chickpea varieties at Fogera Northwest Ethiopia.

Parameters													
Desi type	STC	DF	DPM	NPB	NSB	NPP	NSP	PH (cm)	PCH	BMY (Kg/ha)	GY (Kg/ha)	HI (%)	HSW (gm)
Teketay	76.7a	55.3^{b}	116.7^{b}	12.4^{a}	15.3^{a}	54.2^{a}	1.1^{b}	42.3^{b}	36.3^{a}	4311.1^{a}	1883.3^{a}	0.44^{b}	27.3^{ab}
Dalota	75.7^{ab}	51.7^{c}	123.0^{b}	3.7^{b}	13.2^{ab}	41.2^{b}	1.3^{ab}	42.3^{b}	37.7^{a}	4314.5^{a}	1891.9^{a}	0.44^{b}	25.6^{b}
Geletu	73.7^{ab}	48.0^{d}	102.3^{c}	4.2^{ab}	15.5^{a}	45.5^{b}	1.3^{ab}	37.9^{b}	35.7^{ab}	4389.5^{a}	1976.4^{a}	0.46^{ab}	30.0^{a}
Eshete	79.0^{a}	62.0^{a}	134.3^{a}	3.7^{b}	12.1^{bc}	29.4^{c}	1.6^{a}	52.1^{a}	33.3^{b}	2472.2^{b}	1166.7^{b}	0.50^{ab}	16.7^{c}
Local	70.3^{b}	55.0^{bc}	119.7^{b}	3.5^{b}	9.9^{c}	18.9^{d}	1.1^{b}	41.1^{b}	24.3^{c}	2040.0^{b}	1066.7^{b}	0.53^{a}	16.7^{c}
CV	4.02	3.6	3.9	12.4	12.5	8.2	15.5	5.6	4.4	11.9	7.4	9.7	9.2
LSD	5.7	3.7	8.7	0.94	3.1	5.8	0.4	4.6	2.8	785.1	223.5	0.09	4.1
Kabuli type													
Ejere	69.0^{b}	55.0^{a}	134.3^{a}	4.3^{ab}	13.1^{b}	53.8^{ab}	1.3^{a}	52.8^{b}	32.3^{c}	3666.7^{b}	1615.3^{c}	0.45^{a}	28.7^{c}
Hora	73.7^{a}	54.3^{a}	134.7^{a}	4.6^{a}	15.3^{ab}	57.5^{ab}	1.1^{a}	52.8^{b}	36.3^{b}	4805.6^{ab}	2097.2^{ab}	0.44^{a}	31.0^{b}
Dhera	74.3^{a}	54.3^{a}	138.3^{a}	4.7^{a}	16.9^{a}	46.3^{ab}	1.3^{a}	65.0^{a}	37.7^{ab}	5000.0^{a}	2047.2^{abc}	0.41^{a}	33.3^{a}
Koka	74.3^{a}	50.7^{b}	123.3^{b}	4.3^{ab}	14.8^{ab}	68.3^{a}	1.1^{a}	48.5^{b}	38.3^{a}	5277.8^{a}	2430.6^{a}	0.46^{a}	35.0^{a}
Shasho	70.3^{b}	55.0^{a}	134.7^{a}	3.2^{b}	15.2^{ab}	42.4^{b}	1.0^{a}	49.7^{b}	33.3^{c}	4666.6^{ab}	1972.2^{bc}	0.43^{a}	28.0^{c}
CV	2.3	3.4	1.6	13.6	11.5	22.9	22.2	8.3	2.6	13.5	11.6	7.1	2.9
LSD	3.1	3.5	4.2	1.1	3.3	23.2	0.5	8.4	1.8	1186.9	444.5	0.06	1.8

Abbreviations: LSD: Least significant difference; CV: Coefficient of variation, Rep: replication; Loc: location; df: degree of freedom; Var: Variety; STC: seedling stand count; DF: Days of flowering; DPM: Days of physiological maturity; NPB: number of primary branches; NSB: number of secondary branches; NPP: number of pod per plant: NSP: number of seed per pod; PH: plant height; PCH: plant count at harvest; GY: grain yield; HSW: hundred seed weight; BMY: biomass yield and HI: harvest index; ***:significant; ns: non-significant. Means with the same letter in same column are not significantly different and vice versa.

Table 6
Mother trail mean performance of Desi and Kabuli type chickpea varieties combined over locations.

Parameters													
Desi type													
	STC	DF	DPM	NPB	NSB	NPP	NSP	PH (cm)	PCH	GY (Kg/ha)	BMY (Kg/ha)	HI (%)	HSW (gm)
Teketay	77.0^{a}	57.7^{b}	118.2^{c}	4.8^{a}	14.8^{a}	64.9^{ab}	1.2^{bc}	51.6^{b}	37.3^{a}	2327.8^{a}	5019.5^{a}	0.46^{b}	27.3^{ab}
Dalota	76.2^{a}	57.3^{b}	124.0^{b}	3.7^{b}	12.6^{a}	68.4^{a}	1.4^{b}	46.4^{c}	37.5^{a}	2175.9^{ab}	4876.7^{a}	0.45^{b}	25.0^{b}
Geletu	74.2^{ab}	55.2^{c}	111.8^{d}	3.7^{b}	14.7^{a}	63.1^{ab}	1.3^{bc}	44.8^{c}	35.5^{b}	2123.6^{b}	4972.6^{a}	0.43^{b}	29.3^{a}
Eshete	77.7^{a}	63.8^{a}	137.7^{a}	4.6^{ab}	14.4^{a}	50.6^{b}	1.8^{a}	62.6^{a}	34.3^{b}	1569.5^{c}	3569.4^{b}	0.46^{b}	16.7^{c}
Local	72.2^{b}	56.7^{bc}	122.8^{bc}	3.9^{ab}	17.5^{a}	30.4^{c}	1.2^{c}	50.1^{b}	30.7^{c}	1211.0^{d}	2120.0^{c}	0.55^{a}	19.5^{c}
GM	75.4	58.1	122.9	4.09	14.8	55.5	1.4	51.1	35.1	1881.5	4111.6	0.47	23.6
CV	4.3	2.9	3.4	20.8	40.6	22.9	14.9	4.8	3.5	7.6	8.6	10.4	12.7
LSD	3.9	2.1	5.1	1.03	7.3	15.6	0.3	2.9	1.5	173.9	432.2	0.06	3.7
Kabuli type													
Ejere	68.3^{c}	58.2^{a}	129.0^{b}	4.2^{ab}	13.8^{a}	56.5^{a}	1.3^{a}	54.1^{b}	31.3^{e}	2108.4^{b}	4829.7^{c}	0.44^{ab}	29.2^{c}
Hora	71.2^{b}	59.0^{a}	136.7^{a}	4.3^{ab}	16.0^{a}	54.3^{a}	1.1^{a}	54.2	32.8^{d}	2103.5^{b}	5156.3^{bc}	0.41^{b}	31.8^{b}
Dhera	72.8^{b}	58.2^{a}	139.7^{a}	4.7^{a}	15.5^{a}	49.0^{a}	1.2^{a}	68.8^{a}	36.5^{b}	2325.7^{b}	5555.6^{ab}	0.42^{b}	33.7^{ab}
Koka	75.8^{a}	55.5^{b}	120.2^{c}	3.9^{ab}	13.7^{a}	61.9^{a}	1.2^{a}	51.7^{b}	38.5^{a}	2813.2^{a}	5902.8^{a}	0.48^{a}	35.3^{a}
Shasho	72.0^{b}	60.3^{a}	130.5^{b}	3.8^{b}	15.4^{a}	51.3^{a}	1.2^{a}	54.2^{b}	34.7^{c}	2212.5^{b}	5388.9^{abc}	0.41^{b}	28.0^{c}
GM	72.03	58.23	131.20	4.19	14.89	54.60	1.21	56.59	34.77	2312.6	5366.7	0.433	31.6
CV	2.1	3.2	3.1	15.6	14.5	21.9	21.7	10.2	2.4	10.4	9.4	8.9	5.2
LSD	1.8	2.3	4.9	0.8	2.6	14.6	0.3	7.02	0.9	186.41	616.3	0.04	2.0

Abrevaitions:LSD:Least significant difference,; CV:Coefficient of variation, STC:seedling stand count; DF: Days of flowering; DPM:Days of physiological maturity; NPB:number of primary branches; NSB:number of secondary branches; NPP:number of pod per plant; NSP:number of seed per pod; PH:plant height; PCH:plant count at harvest; GY:grain yield; BMY: biomass yield and HI: harvest index. ns:non-significant. Means with the same letter in same column are not significantly different and vice versa.

with 76.3. Among the Desi type chickpea varieties, Eshete was the tallest with a height of 73.2 cm, followed by Teketay with 60.3 cm. Additionally, Eshete (5.40) and the Local check (25.0) had the highest number of primary and secondary branches per plant (NPB, NSB) (Table 4). Besides that, the variety Koka had the highest seedling stand count (STC) at 77.3, followed by Local check at 73.7. However, Dhera and Hora had the highest number of primary and secondary branches per plant (NPB, NSB) with 4.7 and 16.8 respectively. In addition, the variety Dhera (72.7 cm) and the Local check (58.6 cm) were the tallest among Kabuli type chickpea varieties as shown in Table 4. This suggests that the Dhera variety is one of the most promising options for the future in Adet areas. The height of chickpea plants can range from 20 to 100 cm, but under suitable conditions, tall cultivars can grow up to 130 cm [3]. In the location of Fogera, the variety Eshete showed the highest mean values of seedling stand count (STC) and plant height (PH), with 79.0 and 52.1 cm, respectively. The variety Teketay followed closely with a seedling stand count of 76.7. Among the Desi type chickpea varieties, the highest mean values of both primary and secondary branches per plant (NPB.NSB) were found in Teketay (12.4, 15.3)

and Geletu (15.5), according to Table 5. Among the Kabuli chickpea varieties, Koka and Dhera showed the highest seedling stand count (STC), both recording 74.3. Dhera also had the highest number of primary and secondary branches per plant (NPB, NSB) at 4.7 and 16.9 respectively, as well as the tallest plant height at 65.0 cm (Table 5).

3.3.4. Phenological traits

Among the Desi chickpea varieties, Geletu (55.2, 111.8 days) followed by Local check (56.7, 122.8 days) and Teketay (118.2 days) were found to be the earliest in both 50 % flowering (DF) and 90 % days to physiological maturity (DPM). On the other hand, Eshete (63.8, 137.7 days) was too late in reaching these milestones. Similarly, Koka (55.5, 120.2 days) was observed to be the earliest while the Local check (60.3 days) and the variety Dhera (139.7 days) were the latest in both days to 50 % flowering (DF) and 90 % physiological maturity (DPM) respectively (Table 6).

At Adet location, the Teketay variety (60.0, 119.7 days) is the earliest in both days of 50 % flowering (DF) and 90 % physiological maturity among the Desi type chickpea varieties. Similarly, the Koka variety (60.3, 117.0 days) is also the earliest in both days of 50 % flowering (DF) and 90 % physiological maturity (DMP) in the Kabuli type chickpea varieties, as shown in Table 4. In the Fogera location, the earliest Desi chickpea variety to reach 50 % flowering and 90 % physiological maturity was Geletu, taking 48.0 and 102.3 days respectively. Similarly, the Kabuli chickpea variety Koka was also the earliest to reach both 50 % flowering and 90 % physiological maturity, taking 50.7 and 123.3 days respectively (Table 5).

Image1: Taken January 29 at Fogera District Geina Kebele

Image 2: Taken February 8 at Yelemana Denesa (Adet) District Senekengha Kebele

Fig. 3. Farmers' at Fogera (left) and Adet (right) during farmers variety evaluation and selection process.

3.4. Farmers' variety evaluation: perceptions and preferences

Fifteen farmers, both male and female, were chosen based on their extensive knowledge, expertise, and experience in chickpea cultivation, as well as their willingness to participate in the trial. The research station's technical assistants, development agents from each Kebele, and researchers were all heavily involved in this process (Fig. 3). Before selecting farmers, we conducted a Farmer Researcher Focus Group Discussion (FREFGD) to identify the challenges and obstacles associated with chickpea production in a specific district and Kebeles (Fig. 3). The farmers were engagedin evaluating and selecting varieties based on disease resistance (DR),

Table 7
Pair-wise selection criteria and direct matrix ranking of Desi and Kabuli chickpea varieties at Adet station, Senekengha Kebele West Gojjam zone in 2022/23 main season of the crop.

Pair-wise ranking matrix of farmers' evaluation and selection criteria

Selection criteria	Grain Yield (GY)	Disease resistance (DR)	Early mature (EM)	Short in height (SH)	High Canopy Cover (HCC)	Pod number per plant and pod size (NPPPS)	Similarity with other types of crops (SOTC)	Total Score	Rank	Weight
Grain yield (GY)	X	GY	GY	DR	DR	DR	DR	6	1	1
Disease resistance (DR)		X	GY	GY	EM	GY	EM	5	2	2
Early mature (EM)			X	EM	EM	GY	DR	4	3	3
Short in height (SH)				X	NPPPS	NPPPS	SH	1	6	6
High Canopy Cover (HCC)					X	HCC	HCC	2	5	5
Pod number per plant and Pod size (NPPPS)						X	NPPPS	3	4	4
Similarity with other types of crops (SOTC)							X	0	7	7

Direct matrix ranking of Desi and Kabuli type chickpea varieties for the selected traits by the farmers

Selection criteria	Weight of Criteria	Desi type Teketay	Dalota	Geletu	Eshete	Local	Kabuli type Ejere	Hora	Dhera	Koka	Local
Grain Yield (GY)	1	2.3 (2.3)	3 (3)	1 (1)	5 (5)	4 (4)	4 (4)	3.1 (3.1)	1(3)	1 (1)	4.3 (4.3)
Disease resistance (DR)	2	2.1 (4.2)	5 (10)	2 (4)	1.5 (3)	3.1 (6.2)	2 (4)	5 (10)	2.6 (5.2)	1.1 (2.2)	5 (10)
Early mature (EM)	3	2.2 (6.6)	3(9)	1.5 (4.5)	5 (15)	4 (12)	2 0.1 (4.2)	2 (6)	4.5 (13.5)	1.5 (4.5)	3 (9)
Short in height (SH)	6	1 (6)	0.8 (4.8)	1 (6)	3 (18)	2 (12)	0.7 (5.2)	1 (6)	5 (30)	1.2 (7.2)	2.5 (15)
High Canopy Cover (HCC)	5	1.1 (5.5)	2 (10)	1 (5)	3 (15)	4.3 (21.5)	3 (15)	1.2 (6)	2.5 (12.5)	1.1 (5.5)	4.5 (22.5)
Pod number per plant and pod size (NPPPS)	4	3 (12)	2.3 (9.2)	2.3 (9.2)	2 (8)	3.2 (12.8)	1.5 (6)	2.4 (9.6)	1 (4)	1 (4)	4.3 (17.2)
Similarity with other types of crops (SOTC)	7	2 (14)	1.7 (11.9)	2 (14)	2.2 (15.4)	1.7 (11.9)	5 (35)	3 (21)	1.7 (11.9)	2.3 (15.1)	2.6 (18.2)
Total		50.6	57.9	43.7	79.4	80.4	73.4	61.7	80.1	39.5	96.2
Over all rank		2	3	1	4	5	3	2	4	1	5

Note: Numbers out of () are mean scores given by farmers for each variety with each evaluation criteria (1 = Very good, 2 = good, 3 = satisfactory, 4 = poor and 5 = very poor) and numbers in () are the product of the weight of the evaluation criteria and the mean scores of varieties.

grain yield (GY), early maturity (EM), short height (SH), number of pods per plant (NPP), high canopy covers (HCC), and similarity with other types of crops (SOTC) at Adet Senkengha and Mousobo Kebeles (Tables 7 and 8). Furthermore, in the Geina Kebele of Fogera location, farmers have selected their choice of criteria for identifying the best varieties. These criteria include grain yield (GY), disease resistance (DR), early maturity (EM), short height (SH), high canopy cover (HCC), pod number per plant (NPP), pod size (NPPPS), branch and stem strength (BSS), suitability for black soil (SBS), and high biomass (BM)(Table 9). Groups of farmers using a specific set of criteria evaluated each variety of chickpea (Fig. 3). The scores were given on a scale of 1–5, with 1 being very good and 5 being very poor. The scores for each evaluation criterion were added together and then averaged. The overall value of each variety was calculated by multiplying the weight of the evaluation criteria by the mean of scores for each variety's selection criteria. Finally, the varieties were ranked according to their overall value, with the lowest sum ranking coming first. At Adet location, farmers selected three Desi and three Kabuli chickpea varieties, namely Geletu, Teketay, Dalota and Koka, Hora, and Ejere at Senkengha Kebele were chosen as the best improved chickpea varieties in that order(Table 7). At Mousobo Kebele, Teketay, Geletu, and Dalota were chosen as the best Desi varieties, and Dhera, Koka, and Hora were chosen as the best Kabuli varieties (Table 8). At Fogera location, Geina Kebele, farmers selected Geletu, Teketay, and Dalota as the best Desi varieties, and Shasho, Koka, and Ejere as the best Kabuli varieties (Table 9).

4. Discussion

The analysis of variance (ANOVA) revealed highly significant ($P \leq 0.01$) and significant ($P \leq 0.05$) differences in phenological, growth, yield, and related traits due to the main effects of varieties, locations, and their interaction. Showing the presence of adequate variability due to the nature and genetic makeup, among the evaluated improved chickpea varieties, that could be attributed to the genetic potential for the traits under consideration. In addition, this genetic variability seems to be important for the future chickpea breeding program, which focuses on phenotypic and molecular descriptions of such genetic resource producing novel and high yielding improved varieties [5]. Tlahun et al. [13] also observed a significant difference in grain yield and related components among chickpea varieties across different agro ecologies in Ethiopia. Similar results was reported by Mohammed et al. [6] who found that chickpea varieties significantly differed in biomass and grain yield per plant. Amara and Kassahun [6] also reported similar results on different varieties of common bean varieties. In addition, studies conducted by Abate et al. [14] showed a significant variation among

Table 8
Pair-wise selection criteria and direct matrix ranking of Desi and Kabuli chickpea varieties at Adet station, Mousebo Kebele West Gojam zone in 2022/23 main season of the crop.

Pair-wise ranking matrix of farmers' evaluation and selection criteria

Selection criteria	Grain Yield (GY)	Disease resistance (DR)	Short in height (SH)	Early mature (EM)	High Canopy Cover (HCC)	Pod number per plant and pod size (NPPPS)	Total Score	Rank	Weight
Grain Yield (GY)	X	EM	GY	GY	GY	EM	5	1	1
Disease resistance (DR)		X	GY	DR	DR	DR	4	2	2
Short in height (SH)			X	NPPPS	HCC	GY	0	6	6
Early mature (EM)				X	EM	DR	3	3	3
High Canopy Cover (HCC)					X	HCC	2	4	4
Number of Pod per plant and Pod size (NPPPS)						X	1	5	5

Direct matrix ranking of Desi and Kabuli type chickpea varieties for the selected traits by the farmers

Selection criteria	Weight of Criteria	Desi type Teketay	Dalota	Geletu	Eshete	Kabuli type Local	Ejere	Hora	Dhera	Koka	Local
Grain Yield (GY)	1	1.2 (1.2)	3 (3)	1 (1)	5 (5)	4 (4)	4 (4)	3.1 (3.1)	1(1)	1 (1)	2.3 (2.3)
Disease resistance (DR)	2	2.1 (4.2)	5 (10)	4.5 (9)	1.5 (3)	3.1 (6.2)	5 (10)	5 (10)	2.5 (5)	1.1 (2.2)	3.7 (7.4)
Short in height (SH)	6	2.5 (15)	3 (18)	1.5 (9)	5 (30)	4 (24)	2.1 (12.6)	2 (12)	4.5 (27)	1.5 (9)	2(12)
Early mature (EM)	3	2 (6)	2.5 (7.5)	1 (3)	4 (12)	3.4 (10.2)	4.8 (14.4)	2 (6)	1.5 (4.5)	1.2 (3.6)	2.5 (7.5)
High Canopy Cover (HCC)	4	1.1 (4.4)	3.7 (14.8)	1 (4)	3 (12)	4.3 (17.2)	3 (12)	1.2 (4.8)	1 (4)	1.1 (4.4)	2.5 (10)
Pod number per plant and Pod size (NPPPS)	5	1.5 (7.5)	3.3 (16.5)	2.3 (11.5)	4 (20)	4.2 (21)	1.5 (7.5)	2.4 (12)	1 (5)	1 (5)	4.3 (21.5)
Total		38.6	69.8	40.5	82	82.6	60.5	47.9	46.5	25.2	60.7
Over all rank		1	3	2	4	5	4	3	2	1	5

Note: Numbers out of () are mean scores given by farmers for each variety with each evaluation criteria (1 = Very good, 2 = good, 3 = satisfactory, 4 = poor and 5 = very poor) and numbers in () are the product of the weight of the evaluation criteria and the mean scores of varieties.

Table 9
Pair-wise selection criteria and direct matrix ranking of Desi and Kabuli chickpea varieties at Fogera station, South Gonder zone in 2022/23 main season of the crop.

Pair-wise ranking matrix of farmers' evaluation and selection criteria												
Selection criteria	Grain Yield (GY)	Disease resistance (DR)	Early mature (EM)	Short height (SH)	High Canopy Cover (HCC)	Pod number per plant and pod size (NPPPS)	Branch and Stem strength (BSS)	Suitability for the black soil (SBS)	High biomass (BMF)	Total Score	Rank	Weight
Grain Yield (GY)	X	GY	DR	GY	GY	GY	EM	GY	GY	8	1	1
Disease resistance (DR)		X	DR	DR	EM	DR	DR	DR	SBS	6	3	3
Early mature (EM)			X	EM	EM	HCC	GY	SBS	EM	5	4	4
Short in height (SH)				X	GY	SBS	NPPPS	SBS	SBS	0	9	9
High Canopy Cover (HCC)					X	HCC	NPPPS	BM	HCC	3	6	6
Pod number per plant and pod size (NPPPS)						X	NPPPS	NPPS	BM	4	5	5
Branch and Stem strength (BSS)							X	SBS	SBS	1	8	8
Suitability for the black Soil (SBS)								X	BSS	7	2	2
High biomass (BM)									X	2	7	7
Direct matrix ranking of Desi and Kabuli type chickpea varieties for the selected traits by the farmers												
Selection criteria	Weight of Criteria	Desi type Teketay	Dalota	Geletu	Eshete	Local	Kabuli type Ejere	Hora	Dhera	Koka	Local	
Grain Yield (GY)	1	1.2 (1.2)	3 (3)	1 (1)	3.5 (3.5)	2.5 (2.5)	1.8 (1.8)	3.5 (3.5)	3.2 (3.2)	1.5 (1.5)	1 (1)	
Disease resistance (DR)	3	2.1 (6.3)	3.6 (10.8)	1.5 (4.5)	1 (3)	1.4 (5.2)	2.1 (6.3)	1.4 (5.2)	3.3 (9.9)	1 (3)	2.5 (7.5)	
Early mature (EM)	4	2.5 (10)	3 (12)	1.5 (6)	5 (20)	1.2 (4.8)	2.5 (10)	1.2 (4.8)	3 (12)	1.5 (6)	1.5 (6)	
Short in height (SH)	9	2 (18)	1.5 (13.5)	1 (9)	2.1 (18.9)	2.1 (18.9)	2 (18)	1.1 (18.9)	1.2 (10.8)	2 (18)	1 (9)	
High Canopy Cover (HCC)	6	1.1 (6.6)	1.7 (10.2)	1 (6)	2 (12)	2 (12)	1.1 (6.6)	2 (12)	1.7 (10.2)	1.1 (6.6)	1.1 (6.6)	
Pod number per plant and pod size (NPPPS)	5	1.5 (7.5)	2.3 (11.5)	1.3 (6.5)	3 (15)	3 (15)	1.5 (7.5)	2 (10)	2.3 (11.5)	1 (5)	1.3 (6.5)	
Branch and Stem strength (BSS)	8	2 (16)	2.4 (19.2)	2 (16)	2 (16)	2 (16)	2 (16)	2 (16)	2.4 (19.2)	2 (16)	2 (16)	
Suitability for the black Soil (SBS)	2	1 (2)	2.1 (4.2)	3 (6)	2 (4)	1 (2)	1 (2)	1 (2)	2.1 (4.2)	1 (2)	1 (2)	
High biomass (BMF)	7	1.3 (9.1)	1.5 (10.5)	2.1 (14.7)	1 (7)	3 (21)	1.2 (8.4)	2 (14)	1.5 (10.5)	1.3 (9.1)	1.1 (7.7)	
Total		76.2	94.9	69.7	99.4	97.4	76.6	86.4	91.5	67.2	64.3	
Over all rank		2	3	1	5	4	3	4	5	2	1	

Note: Numbers out of () are mean scores given by farmers for each variety with each evaluation criteria (1 = Very good, 2 = good, 3 = Satisfactory, 4, Poor and 5 = Very poor) and numbers in () are the product of the weight of the evaluation criteria and the mean scores of varieties.

different grass pea types in terms of plant height (PH), number of primary branches per plant (NPB), number of pods per plant (NPP), number of seeds per pod (NSP), days to flowering (DF), days to maturity (DM), hundred seeds weight (HSW), and seed yield per plant. This variation was due to both environmental conditions and genetic differences among the plant materials. These findings confirm that breeding programs have successfully developed improved chickpea varieties with distinct genetic identities. In the same way Tlahun et al. [13] reported similar results on the phenological, growth, yield, and related traits of improved chickpea varieties across different agro ecologies of the crop in Ethiopia.

Introducing adapted and high yielding crop varieties for crop producers is a proven method of enhancing productivity while minimizing costs and reducing time. The results section of this experiment indicates that the highest combined mean value of grain yield in the mother trial was obtained from the following varieties: Teketay (2327.8 kg/ha), followed by Dalota (2175.9 kg/ha) and Geletu (2123.6 kg/ha) in the Desi chickpea; and Koka (2813.2 kg/ha) followed by Dhera (2325.7 kg/ha) in the Kabuli chickpea. Similarly, Abebe and Birhanu [15] shows that in an on farm experiment, the variety Teketay had the highest grain yield of 2274 kg/ha, followed by Dalota with 1892 kg/ha. The same report also mentions that Dalota had the highest grain yield of 3038 kg/ha. However, the report further states that the variety Habru had the highest mean grain yield of 1822 kg/ha, based on the overall mean grain yield of the Kabuli chickpea. This suggests that the different varieties have performed differently in various locations due to variations in the environment and genetic makeup, which could be the possible explanation for the observed differences. The variability in yield performance of improved varieties may be due to differences in soil fertility status and other abiotic and biotic factors [16]. Moreover, chickpeas have the potential to fill the legume gap during winter after the summer crop harvest, such as rice. They can also help address numerous problems faced by resource poor farmers, including malnutrition, low soil fertility, and land degradation. Therefore, strong promotion in different potential area is highly essential [3].

Morphological and yield-related traits, such as plant height and number of pods per plant, can be strongly influenced by the variety and growing environment [6]. According to Taye and Ayenew [16] short plant height is attributed to drought and heat stress tolerance, which could lead to lower water loss through transpiration and ultimately reduce water stress throughout the crop growth period in grass pea accessions. Nevertheless, under non moisture stress conditions, tall plant highest is very important to produce higher number of branches as well as number of pods per plant which results high amount of grain yield [17]. As indicated in the result section of this experiment the variety Geletu is the shortest while the variety Dhera is the tallest provides tobe one of the promising varieties of the future chickpea breeding program at Adet and Fogera stations. The overall plant height of chickpea ranges from 20 to 100 cm, although tall cultivars undersuitable conditions can grow up to 130 cm [3]. Moreover, there was performance difference on phenological traits across location with in all varieties. Similarely Korbu et al. [9] who reported that always there has to be considerable variation in the days to flowering and maturity period on different chickpea varieties when planted under various environments, thus earlier maturity gives advantages for that variety because it can escape harsh environmental conditions [9]. Dembi et al. [18] Reported that, the earlier maturity period of chickpeas could be about 74 days while the longest has to be 144 days.

Based on the results of the experiment, farmers have selected the three best varieties of Desi and Kabuli chickpeas. These are Geletu, followed by Teketay and Dalota, and Local check (Shasho), and followed by Koka, Dhera, Hora, and Ejere. The order applies to Adet Senkengha, Mousobo Kebeles, and Fogera location, Geina Kebele. Improved varieties serve as the foundation of productive agriculture. In this context, improved and farmer-preferred varieties contribute to better agricultural productivity as they respond to farmers' needs and circumstances [6]. Participatory varietal selection has shown success in identifying preferred varieties by farmers in shorter time than the conventional system and thus accelerating their dissemination because PVS provides an effective vehicle to identify farmer preferred varieties and hastens the process of varietal replacement [6]. Researchers and farmers possess their respective and shared knowledge, which should be utilized efficiently in the research process. This implies that clients and researchers must collaborate with each other in developing diverse varieties, which can aid in the quick adoption of new technologies in the farming industry [19]. A significant advantage of participatory variety selection (PVS) is that the implementation and adoption of new varieties is much faster than the formal system, where farmers are presented with only a restricted range of new cultivars [1]. Since farmers have their own indigenous knowledge to evaluate the new varieties, which mainly depend on the importance of that variety in the farming system and its cultivations [8]. Furthermore, selection criteria for farmers should vary based on environmental conditions, traits of interest, ease of cropping systems, processing, use, and marketability [18]. In many Asian countries, such as India, chickpeas are an essential part of crop rotation with rice. Chickpeas can improve soil fertility by fixing atmospheric nitrogen and making it available for crop uptake. As much as 80 % of India's nitrogen necessity is met from symbiotic nitrogen fixation, and chickpeas can fix up to 140 kg of nitrogen per hectare from the air. Additionally, the leaves of chickpeas provide a significant amount of residual nitrogen for subsequent crops and add plenty of organic matter to maintain and improve soil health and fertility [3]. It is highly important for Ethiopia, particularly in areas like Fogera's environment, because the crop is sown at the end of the rainy season following the harvest of the main crop, such as rice. This gives farmers the opportunity to engage in double cropping advantage. Because chickpea production is less labor-intensive and requires fewer external inputs compared to cereals [20,16].

5. Conclusion

The involvement of farmers in the process of evaluating and selecting crop varieties plays a crucial role in the adoption of improved varieties for production. There was a significant difference observed between the studied Desi and Kabuli chickpea varieties. This difference was due to the interaction of varieties with locations on phenology, growth, grain yield, and related traits. This indicates the need for testing new varieties across different locations and seasons to assess their performance. The highest average grain yields were obtained from Teketay (2327.8 kg/ha), followed by Dalota (2175.9 kg/ha) and Geletu (2123.6 kg/ha) in the Desi chickpea variety. Among the Kabuli chickpea varieties, Koka (2813.2 kg/ha) followed by Dhera (2325.7 kg/ha) had the highest yields. At Adet location,

the highest grain yields were recorded from the Teketay variety (2772.2 kg/ha), followed by Dalota (2459.7 kg/ha) and Geletu (2270.8 kg/ha). Among the Kabuli varieties, Koka (3195.8 kg/ha) followed by Dhera (2604.2 kg/ha) and Ejere (2601.4 kg/ha) had the highest yielderss. Farmers in Senkengha Kebele have chosen three Desi and three Kabuli chickpea varieties, specifically Geletu, Teketay, and Dalota, followed by Koka, Hora, and Ejere. Meanwhile, in another Kebele named Mousobo, the three highest producing chickpea varieties were Teketay, Geletu, and Dalota, and from the Kabuli chickpea, Koka, Dhera, and Hora were chosen as the best varieties at Adet location. At Fogera location, the highest mean yield of grain was recorded from Geletu variety (1976.4 kg/ha), followed by Dalota (1891.9 kg/ha) and Teketay (1883.3 kg/ha). Similarly, the Kabuli chickpea varieties produced the highest mean yield from Koka (2430.6 kg/ha), followed by Hora (2097.2 kg/ha) and Dhera (2047.2 kg/ha). In addition, farmers have selected Geletu, Teketay, and Dalota as the top three Desi chickpea varieties, and Shasho, Koka, and Ejere as the top three Kabuli chickpea varieties. In conclusion, understanding the outlook and opinions of farmers regarding the improved varieties of different crops, based on their indigenous knowledge, experience, and cultivation skills is highly important. This is particularly true with crops such as chickpeas. By adopting and disseminating new improved varieties suitable for the local environment, farmers and producers can benefit and access these improved varieties. This ultimately results in the sustainable self-sufficiency of household and country-level food production.

Ethics approval and consent to participate

This paper is based on field observations and contributions of all authors.

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Data availability

The article contains the datasets that were used to obtain our findings but not external data from any repositories.

Consent to participate

Not applicable.

CRediT authorship contribution statement

Mekonnen Gebeyaw: Data curation. **Asnake Fikre:** Supervision. **Alemu Abate:** Supervision. **Tesfahun Alemu:** Software.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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