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Research article

Chickpea production restored through upscaling crowdsourcing winner varieties and planting date adjustments in the Ada'a district, East Shoa zone, Ethiopia

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ABSTRACT

Chickpea is an important cash crop for Ada'a farmers as it does for farmers in Ethiopia and elsewhere in the world. Its production, however, has been dwindling due to biotic and abiotic stresses. According to participant farmers from Ada'a district, the production of chickpea in some Kebeles of Ada'a such as *Gubasaye* has been abandoned because of root rot and foliar diseases such as fusarium wilt. This paper presents the evaluation of upscaled varieties' performance assessed by metric data as well as through beneficiary farmers' self-assessment data. Recognizant to the problem, five varieties of chickpea tested in the Goro district of the Southwest Shoa zone, were introduced as part of the upscaling of crowdsourcing winner crop varieties in Ethiopia. Crowdsourcing is an approach of outsourcing variety evaluation, selection, and dissemination to volunteer crowds of farmers. The introduction of the winner varieties and adjustment of the planting time was found effective in the Ada'a district. Higher grain yield was obtained from the upscaled winner varieties in the range of 2.4–2.53 t/ha, with slight variations over varieties. *Habru* variety showed slightly higher performance than the others. Survey participant farmers have reported an increase in GY due to growing the winner varieties compared with varieties they used to grow before and gained higher annual income due to higher productivity, market demand of the upscaled varieties, and premium market price with 6–25 Ethiopian birr (ETB) per kilogram of sold grain of these varieties. High productivity is attributed to the genetic potential of the varieties, their response to farm management, and better adaptation to the local growing conditions. Participant farmers perceived that their livelihood has been improving because of the adoption of the upscaled varieties' productivity and market demand. The annual income of participant farmers is estimated to be 2500 to 181,000 ETB for growing the winner varieties. The results indicate that upscaling pre-tested chickpea varieties and delaying their planting time to early September are effective mechanisms for reducing yield loss to fusarium wilt and root rot diseases. It can be inferred that using the crowdsourcing approach for variety evaluation and

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selection for upscaling is a robust approach to improve the adoption and dissemination of improved agricultural technologies.

1. Introduction

Chickpea (*Cicer arietinum* L.) is widely grown around the world as a multi-purpose crop spanning from a rich protein source of human food to being an excellent contributor to soil fertility improvement [1–4]. It fixes up to 140 kg N ha^{-1} from the air to meet its nitrogen demands [5,6]. Ethiopia is the leading producer, consumer, and exporter of chickpeas in Africa, and is among the top ten most important producers in the world [7]. According to the 2021/22 report of the Ethiopian Statistical Service (ESS), chickpea accounts for 12 % of areas under pulse crops coverage and 14 % of pulses production share with area coverage of 201,274.14 ha with an annual production of 445,312.72 tonnes [8]. The Amhara and Oromia regions are the dominant chickpea producers with 99 % of the total area allocation and 89 % of the production of chickpea in Ethiopia, according to the same report. Comparing the two giant producing regions, the Oromia region contributes more than the Amhara region in terms of area coverage (54 %) and annual production (50 %) of this crop. Furthermore, east Shoa of the Oromia region is one of the top chickpea-producing zones which accounts for 6 % of the chickpea area with 8 % production in the Oromia region. This zone contributes 3 % of the entire chickpea area and 4 % of its total production nationally [8].

Nevertheless, chickpea production is challenged by low productivity of landraces, poor farming practices, and biotic and abiotic stresses, among others [7]. As the breeding programs continued introducing varieties that have been performing better under limiting conditions; as a result, its productivity showed a slight increase from time to time. The recent statistical data collected by ESS [8] showed that the national productivity of chickpeas is 2.008 t/ha and 1.944 t/ha for the red and white-seeded chickpea varieties, respectively. When downscaled to the Oromia region, the productivity of chickpeas is slightly higher (2.076 t/ha) and 2.043 t/ha) than the national average for both the red and white-seeded chickpea varieties. According to the survey conducted by the ESS [8], however, chickpea productivity in the east Shoa zone including that of Ada'a's district is higher (2.58 t/ha) than its productivity at the national and regional scale [8], probably due to more conducive climatic condition as well as soil types of the zone. Chickpeas are often sown at the end of the main rainy season and grow using residual soil moisture. This nature of the crop allows farmers to practice double cropping, which provides them with an additional source of income and protein.

Farmers have abandoned the production of chickpeas in the Ada'a district of the east Shoa zone due to major yield losses attributed to diseases (*participant farmers' personal communication*). The major diseases identified as intimidators of chickpea production in Ada'a include root rots (fusarium wilt, collar rot, and dry root rot) and foliar diseases (*Ascochyta blight*, botrytis grey mold), and these diseases were identified as important diseases in Ethiopia [9]. A study conducted in 2021 in sampled chickpea production areas of Ethiopia indicated that fusarium wilt and root rot diseases incidence are significantly associated with clay soils (vertisols) type, Desi type chickpea, early planting practice, and early flowering and early plant maturity nature of varieties [10].

It is worth mentioning, however, that the planting date of chickpeas greatly varied from place to place depending mainly on rainfall amount and its seasonal pattern [11,12]. Planting date adjustment helps to mismatch the susceptible development stage of the crop with the occurrence of the disease or other abiotic stresses. The combined use of resistant varieties and planting date adjustment is perceived as the best approach to managing stresses effectively. This study has utilized this approach by distributing pre-tested resistant varieties and advising farmers to delay these varieties' planting by two weeks from the planting date farmers commonly used. In Ada'a farmers used to plant chickpeas around mid-August every year, as early planting in moisture-stressed areas is recommended. Considering the nature of the crop, soil condition, and rainfall distribution, the farmers were advised to do the planting between 28 August to 5 September each year. After three years of production, 120 (37.3 %) out of the 322 direct beneficiary farmers were surveyed using a structured questionnaire to assess the perception of sampled beneficiary farmers in *Gobasaye* Kebele of Ada'a district aiming to capture the performance of the upscaled chickpea varieties and the livelihood improvement of the beneficiary farmers. This paper aimed to inform the benefit of the combined use of resistant varieties of chickpea and sowing time adjustment to improve production and productivity of this crop in areas where production is challenged by soil borne diseases. Furthermore, it presented the perception of beneficiary on the economic generated from growing the upscaled varieties.

Table 1
Chickpea varieties selected from the ISSD project and progressed for further testing and production in the Ada'a district with their economically important characteristics.

No.	Variety	Rank from ISSD stage	Important characteristics distinguished by participant farmers
1	Arerti	1st	High yielder, disease resistance, pest resistance, higher market selling price, attractive seed color.
2	Habru	2nd	Pest resistance, disease resistance, yielder, attractive seed color, higher market selling price
3	Teketay	3rd	Faster maturity, Pest resistance, disease resistance, Yielder, good market selling price
4	Ejere	4th	Disease resistance, Faster maturity, Pest resistance, Yielder, good market selling price
5	Dimitu	5th	Disease resistance, Yielder, Pest resistance, good market selling price

2. Materials and methods

2.1. Description of chickpea varieties

The chickpea varieties upscaled currently were tested together with the other three varieties (*Minjar*, *Naatoli*, and *Dera*) in the Oromia region during the 2017–2019 cropping seasons [13]. The varieties were tested in the southwest Shoa zone at Goro Kebele during the Integrated Seed System Development (ISSD) project time and upscaled to the Ada'a district of the east Shoa zone during the 2020 cropping season and have been under cultivation since then. During the three years of crowdsourcing testing, the eight varieties of chickpea were grown by 50 farmers at *Goro* kebele where each variety was grown and evaluated by 19 farmers. Each farmer has deployed at least three varieties at a time for evaluation and selection purposes as well as increment of his/her chickpea seed portfolio. As shown in Table 1, the participant farmers have mainly evaluated the chickpea varieties against their yielding potential, disease and pest resistance, and market selling price while seed color and maturity time were also considered as important traits in some instances.

Based on these merits, the first three varieties were upscaled to the Ada'a district of the East Shoa zone during the 2020 cropping season through the "Upscaling crowdsourcing winner varieties project", a project jointly implemented by Bioversity International and Oromia Seed Enterprise and commissioned by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) through the Fund International Agricultural Research (FIA). The chickpea varieties included in this study are those publicly available for research through the Ethiopian Ministry of Agriculture. The use of these varieties is fully in compliance with the Ethiopian Ministry of Agriculture variety registration and protection directive and The Plant Treaty on the use of plant genetic resources for food and Agriculture.

2.2. Description of Ada'a district

Ada'a district is one of the thirteen districts in the east *Shoa* zone of the *Oromia* regional state of Ethiopia. The relative location of the district is about 45 km southeast of Addis Ababa, the capital of the country. It is bordered on the south by *Dugda Bora*, on the west by the west *shoa* zone, on the northwest by *Akaki*, on the northeast by *Gimbichu*, and the east by *Lome*. The district has a total population of 185,199, of which 96,024 (51.85 %) are men and the remaining 89,175 (48.15) are women [14]. The district has a land cover of 96,680 ha, of which about 79,517 ha is arable land, and is located in the Great Rift Valley [15,16]. *Ada'a* lies between latitudes of 8°46′ and 8°59′N and longitudes of 38°51′ and 39°04′ E with an altitudinal range of 1540–3100 m above sea level (m.a.s.l) [15,17] with over 90 % of the land lies between 1600 and 2000 m.a.s.l. The project intervention *Kebele was Gubasaye located* 7 km from Bishoftu the town of *Ada'a* district (Fig. 1).

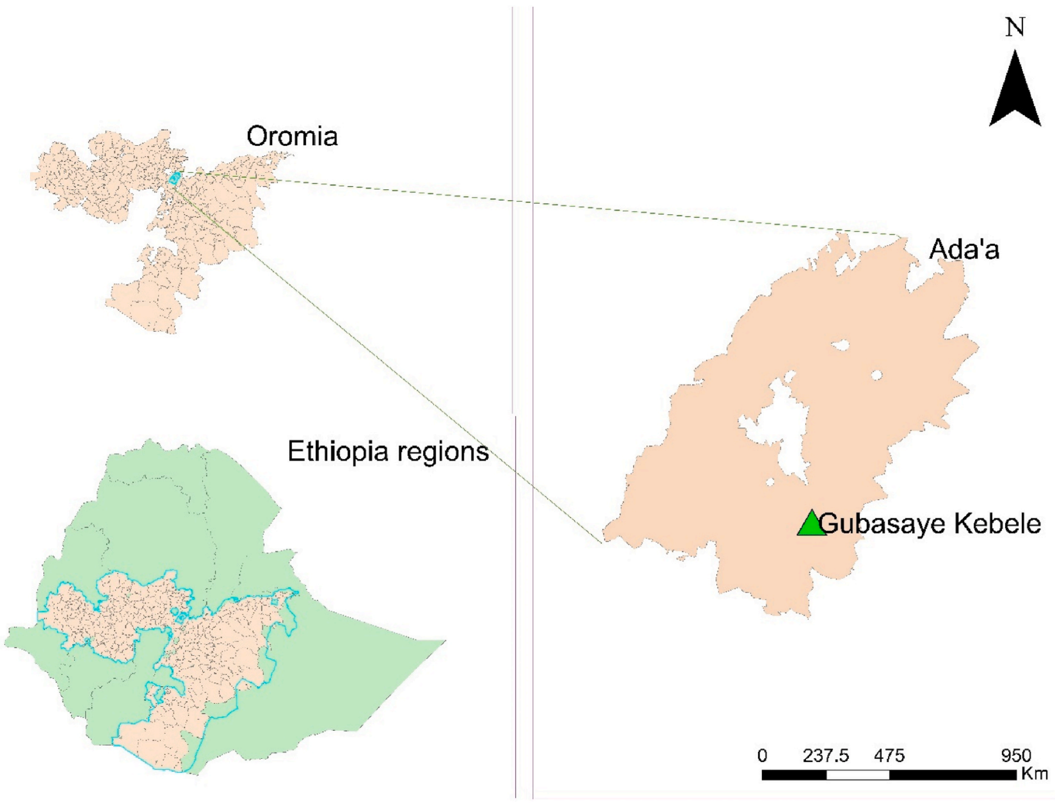

Fig. 1. Map of the study district and Kebele in the Oromia region, Ethiopia.

The district has a typical sub-tropical climate and receives 860 mm of annual rainfall with mean minimum and mean maximum temperatures of 8 °C and 28 °C, respectively. There is consensus that the climate of the Rift Valley, where the district belongs to, is variable with a decreasing trend in annual rainfall amount coupled with variable distribution. On the other hand, the temperature of the area is on increasing trend. Black clay Vertisols is the dominant soil type, with good soil fertility status. The average farm size per household average ranges from 1 to 2.5 ha [17]. The farming system is a mixed crop-livestock production system and the major crops grown are tef, wheat (mainly bread variety), and pulses. Chickpea is the main pulse crop grown in the district and is used as a rotational crop with wheat and teff crops to restore soil fertility.

2.3. Beneficiary farmers sampling

Over the implementation period of the project, 322 farmers were randomly selected in *Gubasaye* Kebele of Ada'a district and agreed to grow the selected winner varieties of chickpeas. Most of these farmers are members of *Abdi Waqa* seed producer cooperative. district and Kebele within the district were purposively selected due to their potential for chickpea production. The indirect beneficiary farmers – farmers who accessed the winner varieties through the direct beneficiary farmers – were selected in mixed methods where most of them were supposed to be selected randomly. The number of indirect beneficiary farmers was assumed to be 8272 over three years.

2.4. Agronomic data collection for the upscaling experiment

Grain yield data of all the upscaled chickpea varieties was collected from sampled direct beneficiary farmers using a 1 m × 1 m (1 m^2) quadrant and was converted to tons per hectare (t/ha). The data collection was carried out in 2021 and 2022 cropping seasons from plots managed by farmers. As a result, variability due to management differences is prominent which prevents the application of rigorous statistical analysis. Instead, the means and range of varietal performance across farmers were presented and discussed. Inter-seasonal variation was minimal and omitted from the discussion. The following simple statistical model was applied to analyze the data, as per the GenStat statistical software:

$$Y_{ij=\mu+gi+sj+ek+\varepsilon ijk} \qquad (1)$$

Where μ is the grand mean; gi is the yield of variety i; sj is the yield variety i at sample j sample; ek is the yield variation of varieties across years and ɛisk is the residual error due to varieties, sampling, and season.

As the variation across seasons was not significant, results were presented only for varieties across samples and presented in Table 2. The least significant difference (LSD) was used to declare varieties performance differences across sampled farmers.

2.5. Household survey

An endline household survey was conducted from September to October 2023 to assess the overall perception of adopter farmers on the contribution of the upscaled varieties to their farm productivity, household food and nutritional security, household income and farm resilience to climate change-induced stresses. This survey tool also helped to triangulate the performance of the varieties and chickpea's diversity increase claim because of the upscaling of the crowdsourcing winner project. Specifically, the survey was designed to capture the contribution of upscaled winner varieties on farmers' varietal portfolio production and productivity of the target crops, resilience, and livelihood improvements of the target beneficiary farmers in the district.

2.5.1. Sampling design and procedures of the household survey

A structured survey questionnaire was designed and executed between the 17th of September and October 8, 2023. The source population was all the direct beneficiary farmers in Ada'a districts, and the 120-study sample was randomly selected from the source population. The sampling procedure used to identify the survey participants was a multistage sampling technique similar to the one mentioned above. The exception here was the selection of farmers from each Kebele was based on stratified random sampling where the farmers were grouped as direct (90 % of the sample) and indirect (10 % of the sample) beneficiaries and from each strata individual

Table 2
Mean grain yield of upscaled chickpea varieties with range value sampled from beneficiary farmers in Ada'a district, east Shoa zone. The values are calculated from the three m^2 quadrant sampled per farm during the 2021 and 2022 cropping seasons.

Sn	Variety	Sample (N)	Mean GY (t/ha)	GY range (t/ha)	Δ
1	Arerti	6	2.40	2.3–2.5	*
2	Dimtu	6	2.51	2.4–2.5	ns
3	Habru	6	2.53	2.5–2.6	*
4	Ejere	6	2.52	2.4–2.7	*
5	Teketay	6	2.44	2.4–2.5	ns
	Average	6	2.47		

Δ Variability analysis on variety performance across farmers; *significantly different at 5 % significance level; ns = non-significant different at 5 % significance level.

farmers were selected randomly.

2.5.2. Data collection of the household survey

The survey instrument was prepared in consultation with the partners and a digital tool, the Kobotoolbox, was used for the data collection. Pre-tested semi-structured questionnaires – originally prepared in English and translated into local language, Afan Oromo – were used in the face-to-face interview. A total of 6 enumerators were recruited for the data collection and were given two days of practical training on the survey instrument and the utilization of Kobotoolbox as a digital data collection tool. The data collection was supervised by facilitators from OSE and ABC staff. Before embarking on the survey, participant consent to participate in the study was obtained by asking the question "Are you interested to participate in this survey?" Their "informed consent" was recorded as "yes" or "no" responses. All participants confirmed their willingness to participate and provided their "informed consent". The survey was conducted in compliance with Bioversity International's Ethics review protocol (https://tip.alliance.cgiar.org/irbSubmissionList/create#!).

2.6. Data analysis

The metric data collected from farmers' plots using the 1 m^2 quadrant from randomly selected farmers in three replications was analyzed for variability using GenStat-18 statistical software. The result was presented in mean form. On the other hand, the collected survey data was analyzed for descriptive statistics such as mean, percentage and increase/decrease trends using Excel and presented as suitable in tables and figures. Due to the nature of the data, we did not apply any rigorous data analysis to the survey data. The experimental protocols were approved by Bioversity International and the funder, BMZ/GIZ, in an approved detailed project proposal. Both field and survey data were collected according to the protocol detailed in the approved proposal, analyzed, and presented in this paper without disclosing the identity of the involved participants.

3. Results

3.1. Productivity improved due to the upscaling effort of chickpea winner varieties

The current project has distributed 8950 kg of seed of five chickpea varieties to 322 direct beneficiary farmers where each farmer was given 10 kg of starter seed. At the end of the third year, these varieties have been grown by 9554 farm households on about 6031.93 ha of land. Grain yield (GY) of each variety was collected from six randomly selected growers, using a m^2 quadrant. The analysis of the collected data showed that the mean GY of the five upscaled varieties ranges from 2.53 t/ha for the Habru variety to 2.4 t/ha for the Arerti variety, with an average productivity of 2.47 t/ha (Table 2). The varieties Habru, Ejere, and Dimtu gave greater than 2.5 t/ha of GY, which is higher than the regional as well as national average GY for chickpeas [8].

Triangulation on productivity improvement was performed by conducting a household survey during 2023 that involved both direct and indirect beneficiary farmers from the district. About 86 % of the surveyed beneficiary farmers have noticed and reported an increase in grain yield of their chickpea because of accessing the crowdsourcing winner varieties, even though 11 % and 3 % of the respondents have reported no change and a decrease in GY after accessing the winner varieties compared to the varieties they have been growing before (Fig. 2A). The yield gained because of growing the winner varieties ranges from 6.25 kg/ha to 125 kg/ha (Fig. 2B). The recorded GY increment varies from grower to grower. About 22 (21 %) of the surveyed HHs have reported a GY gain of less than 25 kg/ha while the majority, 77 (74 %), of them have reported a GY gain of between 25 and 75 kg/ha (Fig. 2B). The remaining sampled farmers have reported a GY gain of greater than 75 kg/ha because of growing the winner varieties of chickpea. This GY gain because of growing the upscaled chickpea varieties could be associated with all or some of farmers preferred traits displayed by the varieties (Fig. 3).

About 98 % of the respondents have associated the gain in GY to the genetic potential of the upscaled varieties. They claimed that

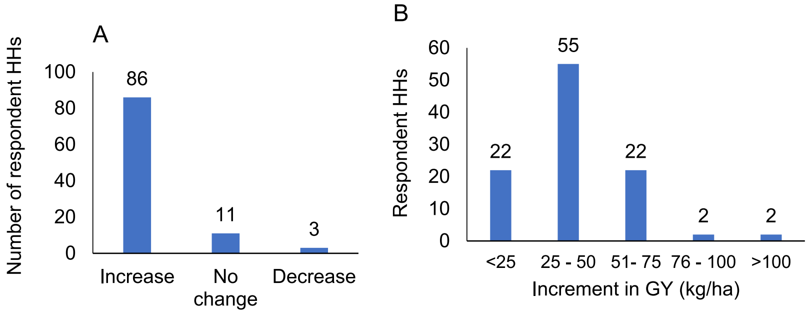

Fig. 2. Response of surveyed households on their farm productivity after accessing the chickpea winner varieties (A) and perceived grain yield change (kg/ha) due to growing the winner varieties (B).

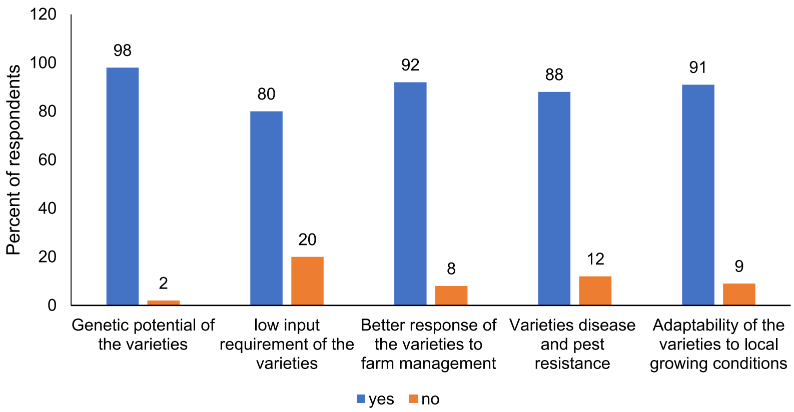

Fig. 3. Attributes identified for better productivity of the upscaled winner varieties of chickpea at Ada'a district.

the upscaled varieties were better than the varieties they had used to grow before. Besides, the upscaled varieties have a better response to farm management practices, better adaptability to diseases and pests and the local growing conditions (Fig. 3). Nonetheless, 14 % of the households (HHs) claimed that their productivity did not change or decrease because of growing the upscaled winner varieties, which might be associated with their poor farm management practice, poor soil fertility or negligence to apply the advised agronomic management (i.e. sowing date adjustment).

3.2. *Farmers' chickpea variety portfolio increased by many folds*

Before the current intervention, farmers in the Ada'a district have abandoned chickpea production for 3–5 years because of fusarium wilt. Taking zero as a benchmark, the varietal portfolio of chickpea has increased in the range of 1–5 (Table 3). About 75 (64 %) of the beneficiary farmers have increased their varietal portfolio by 3–5 chickpea varieties because of either direct access to the varieties from the project or from other beneficiary farmers. Importantly 46 % of the sampled farmers have diversified their varietal portfolio to 5 by accessing all the upscaled chickpea varieties. On the contrary, about 25 % of the participant farmers have in possession of only 1–2 chickpea varieties which might be associated with landholding, variety preference, and/or lack of awareness of the availability of the other varieties in their district. The variety *Arerti* is dominantly possessed by 80 (67.2 %) of the surveyed farmers, which implies that these varieties could be the best suited to their growing conditions. The variety *Dimtu* was the next widely upscaled as grown by 63 surveyed farmers, which might imply that 57.3 % of farmers in the district are growing it.

3.3. *Household annual income and livelihood improvement indicators*

The data collected on household annual income, premium price gained because of growing the winner varieties of chickpea, and indicators of livelihood improvement are presented in Table 4A–C. From our sample, 103 (85.8 %) of the respondents have agreed to an increase in annual household income because of accessing the winner chickpea varieties with an annual income increase ranging from 2500 to 181,000 Ethiopian birr (ETB) (Table 4A). The current results have shown that the production of chickpeas in the Ada'a district is a rewarding business even though this business has collapsed due to disease pressure in the past. About 29 (24.2 %) of participant farmers have reported an annual income of greater than 100,000 ETB or 1791.158 USD at an exchange rate of 1$ = 55.8298 because of accessing and growing the winner varieties on a hectare of land. Acceptance of the varieties in the market, the increased production volume of chickpeas, and diversification of income were the main reasons for the increase in annual household income (Table 4C). Reduction of production cost, as chickpeas do not require much agricultural inputs, was also claimed to contribute

Table 3
Chickpea varietal portfolio of beneficiary farmers at Ada'a district after being involved in the crowdsourcing winner varieties upscaling project.

Sn	Variety	# of farmers accessed it	Percent of adopter farmers	Number of farmers growing N varieties		Percentage (%)
				Variety	Adopters	
				1	13	11
1	*Arerti*	78	67 %	2	28	24
2	*Dimtu*	62	53 %	3	9	8
3	*Ejere*	51	44 %	4	12	10
4	*Habru*	57	49 %	5	54	46
5	*Teketay*	59	50 %	6	1	1
6	Local	6	5 %	Mean = 2.67		
Total HHs surveyed (N = 117)						

Table 4
Annual households' income (A), reasons for income change of households growing the winner varieties of chickpea (B and C), reported factors contributing to increasing household income (D) by chickpea grower farmers in the Ada'a district of Oromia region.

A) Did the Household's income increase because of accessing crowdsourcing winner varieties?		
No	Yes	Respondents number (percent)
17	103	
B) What are the reasons for no increase in your annual income?	Income (ETB) increase range	
Failure of the varieties to perform	2500–20000	26 (25 %)
Low productivity	20001–40000	31 (30 %)
Disease pressure	40001–60000	4 (4 %)
Luck of trust to grow the varieties	60001–80000	4 (4 %)
The same income generated as growing other varieties	80001–100000	9 (9 %)
	100000–120000	14 (14 %)
	120001–140000	13 (13 %)
	>140000	2 (2 %)
	C) Why did your annual income increase?	
	Market demand for the varieties	101 (98 %)
	Reduced production cost	86 (83 %)
	Increased production volume	98 (95 %)
	Diversified income sources (pulses, cereals, straw)	98 (95 %)
	D) How many of the factors contributed to the increase in household income?	
	Farmers reported 2 of the factors	4 (4 %)
	Farmers reported 3 of the factors	21 (20 %)
	Farmers reported 4 of the factors	78 (76 %)

significantly. We have seen that a combination of the factors contributed to the increase in annual income as most farmers, 76 %, have reported all four factors are contributors to their income increase (Table 4D).

Of the surveyed farmers, 17 (14.5 %) have observed no increase in their annual income because of growing the winner chickpea varieties (Table 4B). The enumerated reasons include poor performance of the accessed varieties, disease pressure, and lack of trust in the varieties. It is unsurprising to see variations among grower farmers as technology adoption is influenced by several factors including lack of information support, ineffective dissemination methods, and perception of the proposed technologies. Some farmers perceive they work for the project rather than for themselves when involved in project activities and fail as a result to maximize their benefit.

Surveyed participant farmers unanimously responded that a premium market price is obtained for growing the winner varieties of chickpeas (Fig. 4A), with price gain ranging from 1 to 25 ETB/kg of grain. This might be due to the wider acceptance of these varieties by the local market (Table 4D) to use the winner varieties for seed and also due to the attractive quality attributes of the upscaled varieties (Table 5) ranging from appropriate maturity time (60 %) to good color for market (84 %).

About 60 % of the respondents reported an income gain of 6–15 ETB/kg of grain harvested from the upscaled varieties while about 23 % of them reported 16–25 ETB/kg an increase in price from a sale of the winner varieties. The increase in farm productivity and household income because of the higher market price for their produce has been perceived to influence the livelihood of the grower

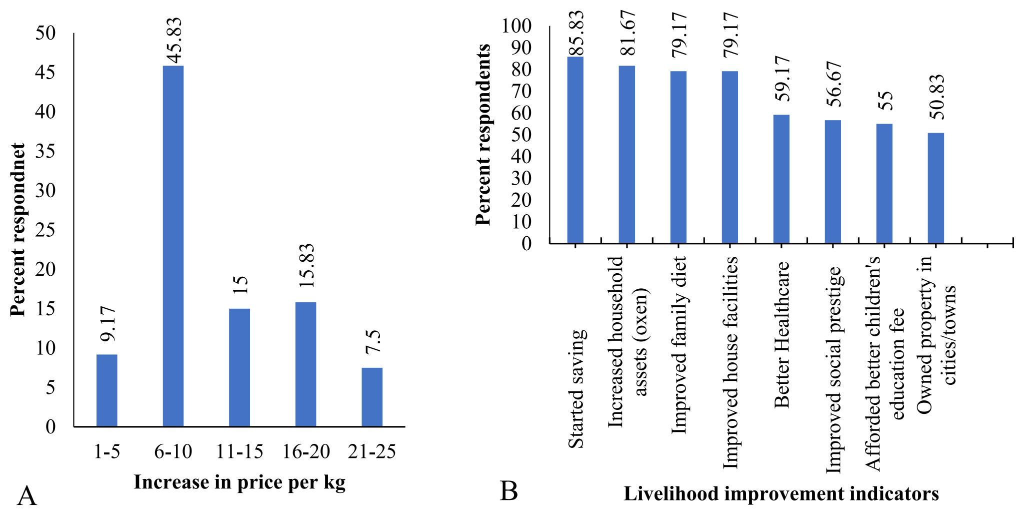

Fig. 4. A) Premium price gained due to growing the winner varieties compared to other alternative chickpea varieties (ETB/kg); B) household livelihood improvement indicators because of growing crowdsourcing winner varieties of chickpea.

Table 5
Attributes of the upscaled chickpea varieties farmers claimed for their preference over the other varieties they used to grow in Ada'a district of east Shoa zone.

Quality attributes of the upscaled chickpea winner varieties	No. of respondents claiming the quality attributes = 86	Percentage[a]
Good color for market	84	98 %
Better taste	77	90 %
Better cooking quality	81	94 %
High and palatable straw	72	84 %
Higher local market price	78	91 %
Cultural values	69	80 %
Maturity time	60	70 %

[a] Percentages can overlap for the respondents were allowed to choose multiple answers.

households (Fig. 3B). According to 85.83 % of the surveyed households, growing upscaled varieties of chickpeas helped farmers to start financial saving in banks. Over 79 % of the surveyed households have noticed that growing these varieties has been improving their household nutrition and increased household assets. Similarly, over 50 % of the respondents claimed that they afforded better schools for their children, accessed better healthcare facilities, and owned properties in a nearby town, Bishoftu.

4. Discussions

Ada'a district is among the major chickpea producers in the east Shoa zone together with Gimbichu, though other districts like *Adami Tulu* and *Jiddo Kombolcha* also have good potential [18]. The productivity of chickpeas in the Ada'a district is higher than its average in the Oromia region and the national productivity [8] which implies the importance of the district for chickpea production. However, its production is challenged by low productivity of landraces, poor farming practices, and biotic and abiotic stresses, among others [7,19]. Of the common diseases affecting the productivity of chickpeas, *Ascochyta rabei*, *Fusarium Oxysporum,* and *Rhizoctonia solani* are recognized as significant economic constraints to chickpea production in Ada'a district [20]. The focus group discussion conducted with Ada'a farmers to identify the crop types to upscale to Ada'a district by Bioversity International and Oromia Seed Enterprise in 2020 enabled us to know the abandonment of chickpea production because of root rot diseases, mostly those mentioned above. Participant farmers affirmed that chickpea production was abandoned in their kebele because of these diseases pressure.

Five chickpea varieties identified for disease resistance and other important traits identified through crowdsourcing trials conducted in the southwest Shoa zone during 2017–2019 were introduced to the Ada'a district (Table 1) by the upscaling crowdsourcing winner varieties project. The use of crop diversity plays a pivotal role in smallholder farmers' ability to cope with and adapt to shocks. Shifting crop varieties and diversifying the crop portfolio are common risk-reduction strategies [21]. The use of high-yielding, disease, and pest-resistant, and other abiotic stress-tolerant varieties, coupled with improved crop management practices, is an indispensable approach for increasing chickpea productivity and production [20]. As crop management practice, adjusting the planting date was included as a package of upscaling. Adopter farmers were advised to delay planting of the upscaled chickpea varieties to late August to early September from the traditional mid-August planting time in the area.

Variety selection and planting date adjustment are reported as effective mechanisms for reducing yield loss attributed to various diseases in chickpeas. For instance, Ali and Habtamu [12] recommended delaying the planting date and growing variety *Mastewal* to maximize chickpea yield and minimize the effect and progression of fusarium wilt at chickpea growing areas in north Shoa. On-station and on-field trials conducted in east Shoa indicated that the adjustment of chickpea planting to early September increased grain yield by 35 % under rainfed conditions [22,23]. Sowing date adjustment greatly varies from place to place. For instance, planting of chickpea can be done at early July in moisture-stressed lowland areas or when planted on sandy soil types [11,12]. In general, planting time is determined by the condition of abiotic and biotic stresses, soil type, and agroecological conditions of the target area. Bilate et al. [23] reported that the sowing of chickpea during mid- September was superior to that planted at mid-Augst and early October in the Meskan district of southern Ethiopia with grain yield advantage of 64 % and 67 %, respectively. The higher grain yield of mid-September planting of this study was due to the availability of favorable soil moisture and less intensity of disease pressure.

The upscaling of crowdsourcing winner varieties of chickpea has increased farmers' varietal portfolio, farm productivity, and household income, and improved households' livelihoods. The average varietal portfolio of farmers' access to varietal diversity ensures stable production of a crop [24], improves productivity [25], and hence, ensures food security. Varietal portfolio effectively addresses location-specific emerging challenges and farmers' preferences [26]. Thus, increasing crop genetic diversity is a noble adaptation strategy in agriculture; especially for marginal environments and vulnerable areas to climate-related risks [25].

As Ethiopia is the top producer, consumer, and exporter of chickpea in the world [7], increasing the varietal portfolio of this crop is uniquely necessary for Ethiopian farmers; to utilize the rich resources, gear towards sustainable quality seed system, and create a stable production of the crops in the face of the current climate change impacts. Sample data collected and analyzed for the various upscaled chickpea varieties confirmed that their grain yield ranged from 2.3 to 2.6 t/ha (Table 2) showing that they perform higher than the national average of about 2 t/ha [8]. The upscaled varieties are in a similar range of productivity even if *Arerti* was dominantly disseminated in the Ada'a district (Table 3). High grain yield is the most perceived farmers' preferred trait worth considering that perhaps underpins better adoption [27]. It has been observed that 86 % of the beneficiary farmers sampled and surveyed reported an increase in farm productivity after adopting the upscaled varieties (Fig. 2A). Empowering farmers to evaluate and select varieties through participatory methods such as crowdsourcing and assessing their feedback on the performance of varieties could accelerate the dissemination and adoption of selected varieties, which the classical variety development scheme lacks [28]. Furthermore, the upscaled chickpea varieties possess attractive preferential qualities such as market-attracting seed color, better taste, better cooking quality, and cultural values – among others (Table 5). Semahegn et al. [27] have reported that higher grain yield potential, resistance to rust diseases, and adaptation to drought and heat stress were among the most perceived farmers' preferred traits to adopt improved bread wheat.

An increase in varietal portfolio accompanied by increased variety productivity plays a significant role in boosting smallholder farm household income and ultimately paving the way to attain household food and nutritional security [29,30]. The annual income of beneficiary farmers growing the winner chickpea varieties ranged from 2500 to 140,000 ETB, a much higher income than growing the other varieties of the same crop (Table 4). The upscaled winner varieties of chickpea were found, both through metric data and survey data, to perform well at Ada'a even though chickpea production has been challenged by root rot diseases. The analysis of collected metric data showed that the grain yield of the upscaled winner varieties of chickpea ranged from 2.4 t/ha for Arerti variety to 2.53 t/ha for *Habru* variety (Table 2). The surveyed farmers not only reported increment per se for GY but also have pinpointed the underlying causes for the increment in grain yield (Fig. 3) ranging from the genetic potential of the varieties to their resistance to pests and diseases. Greater than 80 % of survey participant farmers claimed that the high productivity of the upscaled chickpea varieties is presumably associated with their genetic potential (98 %), low input requirements (80 %); better response to farm management (92 %), resistance to pests and diseases (88 %) and their adaptability to the local growing conditions (91 %). The understanding of the farmers' insight into the performance of the varieties is believed to contribute to better adoption of the varieties which the classical variety development scheme lacks [28]. These traits of crops are among the most perceived farmers' preference traits under marginal production conditions where crop production is constrained by biotic and abiotic stresses [27,31].

The access to adaptable and good-performing crop varieties ensures farm households' productivity, income, and overall livelihood [32–34]. Farm income is to audit both monetary and non-monetary income obtained from farm operations. Survey participant farmers claimed that their annual farm household income increased within a range of 2500 ETB to over 181,000 ETB because of growing crowdsourcing winner varieties of chickpea (Table 4A). The larger variation in farm households' annual income could be associated with the variety accessed and differences in farm management across the farm households [35]. Better annual income because of growing the upscaled varieties presumably associated with their reduced inputs (fungicide, pesticide, and fertilizer), which reduced production cost and the high yielding potential of the varieties. Besides, the upscaled chickpea varieties have higher market demand compared to other varieties of chickpea in the area (Table 4C; Table 5). It has been observed that the majority (>80 %) of farmers growing the upscaled varieties are earning between 6 and 25 ETB more price per sale of a kilogram of chickpea compared to those growing the other chickpea varieties (Fig. 4A). A higher market price premium is usually paid for variety type, seed color and size of seeds, which is highly affected by biotic and abiotic stresses [4]. Participatory engagement of farmers in the evaluation and selection of crop varieties increases farmers' adoption of developed varieties which improve their agricultural production and productivity, household income and overall living standard and consequently reduce poverty. A lower rate of agricultural technology adoption affects these household welfare [36,37]. Hence, the adoption of improved agricultural technology is a precondition for improving the living standards of the rural poor. The access to the upscaled crowdsourcing winner varieties has improved the livelihood of farm households in Ada'a district (Fig. 4B). It has been claimed by survey participant farmers that growing the upscaled varieties has helped them to increase their savings (85.83 %), increased household assets (81.67 %), improved family diet (79.17 %), better household healthcare (59 %) and affordability of sending children to a better school for better education (55 %). Verkaart et al. [38] inferred that the adoption of improved chickpea varieties in Ethiopia has increased growers' household income and reduced poverty and the cultivation of improved chickpea varieties is a promising pathway for rural development in Ethiopia.

The future of food and nutrient security of the world population is partly dependent on the resilience of crops to climate change effect thereby contributing to the enhancement of crop production and productivity and improved livelihood. Varietal technologies coupled with crop husbandry (sowing date adjustment) restored chickpea production in Ada'a district where its production was almost abandoned because of the severe incidence of fusarium wilt and root rot diseases. The access to adaptable crop varieties enables farmers to sustain their farm productivity and reduce challenges of food security [39]. At this point, climate change is projected to escalate the frequency, intensity, spatial dimensions, and duration of extreme weather events, exacerbating the threat to the production and productivity of all major crops. This calls for better access by smallholder farmers to agricultural technologies that perhaps underpin resilient crop production to manage such climatic hazards. Having accessed the winner varieties of the upscaling experiment the target farmers realized farm resilience that can be conspicuously explained by the much higher grain yield of the varieties and better performance under stress conditions.

5. Conclusion and perspectives

The interaction with farmers in Ada'a district pointed out that the production of chickpea has been dwindling because of chickpea root rot and foliar diseases such as fusarium wilt. The decision made to revert the situation by introducing disease-resistant varieties and pushing the planting time from mid-August to early September worked well and now the production of chickpea is well restored in Ada'a with more than 10,000 farmers growing six varieties of chickpea in *Gubasaye* kebele only. The productivity of introduced chickpea varieties through the upscaling crowdsourcing winner varieties ranged from 2.4 to 2.53 t/ha, with slight variations over varieties. *Habru* varieties showed slightly higher performance than the others. According to survey participant farmers, the higher productivity of the varieties could be attributed to their genetic potential, reduced input requirement, better response to farm management, resistance to diseases and pests, and better adaptation to local growing conditions. High productivity and reduced production cost significantly contributed to household annual income, food and nutrition, and overall livelihood improvement. The mean annual income of farmers growing the upscaled chickpea varieties could reach 59607 ETB with a range of 2500 to 181,000 ETB. This might be attributed to the high-yielding nature of the varieties, low production cost, and premium market price – 6–25 ETB/kg – a higher price for the upscaled varieties compared to other varieties in the market. The results indicate that upscaling pre-tested chickpea varieties and delaying their planting time to early September are effective mechanisms for reducing yield loss to fusarium wilt and root rot diseases. It can also be inferred that using the crowdsourcing approach for variety evaluation and selection for upscaling is a robust approach to improve the adoption and dissemination of improved agricultural technologies.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Dejene K. Mengistu: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Hailu Terefe:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Tadesse Teshome:** Writing – review & editing, Project administration, Methodology, Investigation, Formal analysis. **Talila Garamu:** Investigation, Data curation. **Basazen Fantahun Lakew:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Carlo Fadda:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Dejene K. Mengistu reports administrative support was provided by Oromia Seed Enterprise. Dejene K. Mengistu reports a relationship with Alliance of Bioversity International and International Center for Tropical Agriculture that includes: employment. Nothing to declare. If there are other authors, they 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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