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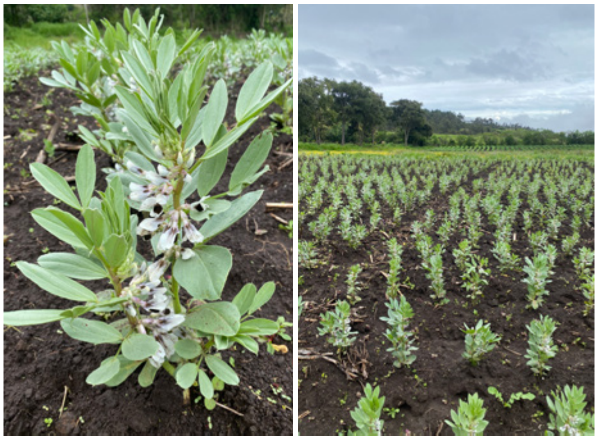
Agronomic evaluation and participatory selection of 64 Faba bean (*Vicia faba* L.) genotypes in Nariño-Colombia

Evaluación agronómica y selección participativa de 64 genotipos de haba (*Vicia faba* L.) en Nariño-Colombia



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Broad bean and experimental batch.

Photos: D.E. Álvarez-Sánchez

ABSTRACT

The participatory selection process of genotypes based on "horizontal dialogue between farmers and breeders" remains limited, especially in legume species related to family farming, such as the Faba bean, a legume associated with food security in southern Colombia. This study aimed to evaluate 64 genotypes of Faba bean of the Regional Argentina variety through agronomic variables and a participatory selection process. An Alpha Lattice design (8×8) with four replications was established to evaluate the number of pods per plant (PP), days to green harvest (DGH), yield (YLD), plant height (PH), and number of seeds per pod (SPP). The participatory selection methodology was employed, allowing farmers to assess the production, plant architecture, and plant health. The agronomic and participatory selection data were integrated into a selection index, identifying the promising Faba bean genotypes. Significant differences were observed for the variables PP, DGH, and YLD, aligning with the farmers' selection based on the three requested traits. The selection index identified thirteen genotypes with an average of 32.65 pods per plant, 137.03 days to harvest, and a yield of 10.26 t ha^{-1}, demonstrating a gain by selection compared to the initial population. Incorporating farmers' preferences in selecting Faba bean genotypes is expected to offer promising material for the high tropics of southern Colombia.

Additional key words: legumes; cultivar selection; family farming; yields.

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RESUMEN

El uso de metodologías de diálogo horizontal entre agricultores y mejoradores para la selección de genotipos sigue siendo limitado, especialmente en especies relacionadas con la agricultura familiar, como el cultivo de haba, una leguminosa asociada a la seguridad alimentaria en el sur de Colombia. Por lo cual, este estudio evaluó mediante variables agronómicas y selección participativa, 64 genotipos de haba de la variedad regional Argentina. Para esto, se estableció un cultivo experimental utilizando un diseño Alfa Lattice (8×8) con cuatro repeticiones, evaluando el número de vainas por planta (PP), días a cosecha en verde (DGH), rendimiento (YLD), altura de planta (PH) y número de semillas por vaina (SPP). Además, se empleó una metodología de selección participativa que permitió valorar por parte de los agricultores la producción, arquitectura de la planta y sanidad. Por último, los resultados fueron integrados en un índice de selección, identificando los genotipos de haba prometedores. Se observaron diferencias significativas en PP, DGH y YLD, coincidiendo con la selección de los agricultores en los tres criterios solicitados. Adicionalmente, el índice de selección permitió identificar trece genotipos con un promedio de 32.65 vainas por planta, 137.03 días a cosecha, y un rendimiento de 10.26 t ha^{-1}, mostrando una ganancia por selección respecto a la población inicial. Se espera que la incorporación de las preferencias de los agricultores permita ofrecer un material promisorio para las condiciones del trópico alto del sur de Colombia.

Palabras clave adicionales: leguminosas; selección de cultivares; agricultura familiar; rendimiento.

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INTRODUCTION

Among legumes for human consumption, Faba bean production stands out as one of the most relevant worldwide, surpassed only by pea, bean, chickpea, and lentil cultivation (Derese, 2022). In this sense, in 2022, 2.68 million hectares of Faba bean were cultivated globally, producing 6.14 million t (FAO, 2024).

The seeds of this crop offer a protein value between 27 and 34% when consumed as fresh vegetables or dry grains, depending on the variety; additionally, they provide fiber, carbohydrates, and minerals (Serafin-Andrzejewska *et al*., 2023). This makes this species a promising candidate for achieving nutritional security in different regions and reducing dependency on animal protein (Ayenew *et al*., 2023; Skovbjerg *et al*., 2023).

In Colombia, the department of Nariño serves as the primary agroecological zone for cultivating this crop, accounting for 75.3% of the national harvest on 500 ha, with an annual production of 1,000 t (MADR, 2022). However, according to Álvarez-Sánchez *et al*. (2022), this department predominantly relies on traditional production methods characterized by late-harvesting materials, susceptibility to lodging, and vulnerability to diseases, resulting in yields below the crop's potential.

Despite these challenges, Nariño also exhibits notable diversity in this species (Álvarez-Sánchez *et al*., 2022; Álvarez *et al*., 2023). This diversity offers an opportunity to identify materials that could serve as productive alternatives for farmers, contributing to the preservation of agroecosystems (Derese, 2022; Skovbjerg *et al*., 2023).

It is imperative to employ strategies that not only consider crop traits but also account for the social, environmental, and economic potential of the region (Díaz-Bautista *et al*., 2008; Hadou el Hadj *et al*., 2022) where they will be implemented by integrating horizontal methodological innovations by the researchers (Brown *et al*., 2020).

In this context, participatory selection (PS) stands out by recognizing that both farmers and professionals possess knowledge and skills that can interact (Mncwango *et al*., 2021; Begna, 2022), proving successful in identifying promising materials in a shorter time, accelerating diffusion, and increasing the exploration of genetic diversity (Kindie and Nigusie, 2019).

In Faba bean cultivation, several successful cases of PS have demonstrated the effectiveness of this approach, with farmers validating the yield potential based on own indicators (Robsa *et al*., 2021; Ayenew *et al*., 2023). Moreover, has facilitated the identification of endogenous preference criteria, which complement and enhance the research process (Díaz-Bautista *et al*., 2008; Kindie and Nigusie, 2019).

Consequently, the interaction between researchers and farmers facilitates the development of research objectives aimed at overcoming the rejection of varieties developed solely by researchers, enhancing their acceptability, and reducing production costs (Begna, 2022). Considering the above, the objective was to conduct the agronomic evaluation and participatory selection of 64 Faba bean genotypes for the Andean region of the department of Nariño in Colombia.

MATERIALS AND METHODS

The experiment was performed between October 2022 and May 2023 in the Mapachico district, municipality of Pasto (Nariño-Colombia) at 2.657 m a.s.l., at 1°14'09" N and 77°18'56" W, an average temperature of 12.6°C, annual precipitation of 808 mm, and relative humidity of 82% (IDEAM, 2023).

In an area of 1.800 m^2, an Alpha Lattice design (8×8) was implemented with four replications and 64 treatments. Each sub-block consisted of eight rows, each 6.6 m in length, with a spacing of 0.8 m between rows. Each row contained a single genotype, with twenty-two seeds planted at intervals of 0.30 m. Evaluations were conducted on twenty plants per row, excluding the plants at the ends.

Based on the physicochemical soil analysis, a soil fertilizer application was carried out at plant emergence, applying N, P_2O_5, and K_2O (kg ha^{-1}) at rates of 94, 55, and 52, respectively. The main phytosanitary issue was *Botrytis fabae*, which was managed through the rotation of carbendazim, benomyl, and prochloraz molecules. Regarding insect pests, preventive applications of imidacloprid and sulfoxaflor were performed.

Genetic material

In 2019, a survey was conducted to identify Faba bean crops of the regional Argentina variety in farmers' fields in the municipality of Pasto, located within an altitudinal range from 2,520 to 3,023 m a.s.l. The selection process focused on plants that exhibited good sanitary condition, vigor, and a high pod load. Seed samples were collected from these selected plants, resulting in a total of 124 genotypes of interest.

During semesters A and B of 2020 and semester B of 2021, this population underwent three cycles of negative selection aimed at eliminating genetic materials characterized by tall plant stature and late harvest periods. This process resulted in the final selection of 60 genotypes, identified sequentially from Ar-01 to Ar-60.

In addition to the selected genetic material, four genotypes previously evaluated by Álvarez-Sánchez *et al*. (2022) were included. These genotypes, identified as 18-L2, 19-L7, 20-L5, and 19-L1, also belong to the regional variety Argentina.

Agronomic evaluation

Using the BBCH phenological scale described in Lancashire *et al*. (1991), at the fruit development stage, the number of pods per plant (PP) and days to green harvest maturity (time from sowing to 90% plant maturity) (DGH) were recorded. After weighing the harvest of ten plants from the row with a scale, the value was converted to t ha^{-1} for each genotype to obtain the fresh yield (YLD). At the maturation stage, the remaining ten plants per genotype were measured for plant height (PH), in cm from the base to the apex of the main stem, and the average number of seeds per pod (SPP).

Analysis of variance – ANOVA (α=0.05) was used for this evaluation. When significant statistical differences were found, genotypes were separated when the variable exceeded the mean plus one standard error ($\mu + \sigma$) or two times its corresponding standard error ($\mu + 2\sigma$), following Lagos *et al*. (2020).

Participatory selection (PS)

The PS methodology with adaptations for Faba bean cultivation was applied (Kindie and Nigusie, 2019; Mncwango *et al*., 2021). Once the experimental crop began its fruit development phase, fourteen experienced farmers in legume production were invited.

In the field, the farmers took a random walk through the entire experiment, and after explaining the methodology, they were asked to rate three criteria: 1) Production, considering the number of pods, pod size, and expected harvest; 2) Plant architecture, considering aspects such as height, number of stems, and leaf area; and 3) Genotype health, considering pest or disease impact, nutritional deficiency, and plant vigor.

Three colored cards were placed in containers at the beginning of each row. Each participant chose twelve genotypes per block, repeating the process four times. Finally, preference was estimated from an aggregated index called Farmer Score (FS). This index was calculated by multiplying the total votes of the participants by a weighting value agreed upon during the activity: 0.6 for production, 0.3 for health, and 0.1 for architecture.

Selection index (SI)

A selection index (SI) was assigned to identify promising Faba bean genotypes. This index is based on the values of agronomic variables that displayed significant differences, along with the FS measurement, using the modified equation (1) (Lagos *et al*., 2020):

$$IS_i = \left[\frac{x_{ij} - m_i}{s_i} * Pi_i\right] + \left[\frac{x_{ij} - m_i}{s_i} * Pi_i\right] \dots + \left[\frac{x_{ij} - m_i}{s_i} * Pi_i\right] \qquad (1)$$

where *xij* was value of trait *i* measured in genotype *j*, *mi* mean of trait *i* measured in the population, *si* standard deviation of trait *i* measured in the population, and *Pis* relative importance weight associated with trait *i*.

In this study, the research group and producers agreed on the following weights: 0.2 for PP, 0.35 for YLD, -0.15 for DGH, and 0.3 for FS.

RESULTS AND DISCUSSION

Agronomic evaluation

In table 1, the analysis of variance showed significant differences among the Faba bean genotypes in terms of the number of pods per plant, days to green harvest maturity, and fresh yield, which indicate the presence of phenotypic variability for these traits and suggest the possibility of selection. In contrast, plant height and the number of seeds per pod did not show significant differences.

Previously documented findings confirm values similar to those found in this study regarding PH and SPP, suggesting that these traits have been influenced by farmer-led selection processes in Nariño (Álvarez *et al*., 2023). This selection has led to the establishment of plants with heights ranging from 85 to 112 cm, and with two to three seeds per pod in the regional variety Argentina (Tab. 1).

This hypothesis aligns with heritability estimates ranging from 0.45 to 0.61 for PH and reaching 0.93 for SPP in Mediterranean and African Faba bean genotypes, showing a high genetic contribution to the phenotypic expression of these characters (Abou-Khater *et al*., 2022; Derese, 2022; Hadou el Hadj *et al*., 2022).

In contrast, table 2 shows that for the PP trait, eight genotypes exceeded the reference value of one standard deviation above the mean. Notably, genotypes Ar-13 with 49.1, 19-L7 with 42.2, and 18-L2 with 46.9 pods exceeded the general mean by more than two

Table 1. Analysis of variance of agronomic traits in 64 Faba bean genotypes.

Source	DF	PH	PP	DGH	YLD	SPP
Genotypes	63	91.88^{ns}	201.9**	139.4*	48.03**	0.25^{ns}
Error	161	10.37	6.91	78.57	6.97	0.03
Block	3	58.31	42.04*	27.30	25.46*	0.006
Sub-block	28	13.48	9.30	111.54	6.28*	0.07
Mean		96.7	20.2	141.1	7.1	2.4
CV		5.92	4.10	4.25	36.5	9.2
R^2		0.61	0.87	0.79	0.80	0.46

PH: plant height (cm); PP: pods per plant; DGH: days to green harvest maturity; YLD: yield (t ha^{-1}); SPP: seeds per pod; CV: coefficient of variation (%), R^2: coefficient of determination; * P-value $\leq$0.05; ** P-value $\leq$0.01.

deviations, the latter demonstrating the selection gain achieved by Álvarez-Sánchez *et al*. (2022).

The population average that revealed statistical differences was 37.7 pods, a result that exceeds the value reported by Kindie and Nigusie (2019) of 13.2, Derese (2022) of 13.9 and Ayenew *et al.* (2023) of 12.9 pods per plant in Africa and Asia. However, this was 12.6% lower than reported by Álvarez-Sánchez *et al*. (2022), which can be explained by the environmental

Table 2. Means of variables evaluated in 64 Faba bean genotypes.

Genotype	PP	DGH	YLD	Genotype	PP	DGH	YLD
Ar-01	24.2	139.9	7.0	Ar-35	20.1	141.1	4.6
Ar-02	18.9	142.6	6.3	Ar-36	14.3	142.2	5.7
Ar-03	21.8	129.9^{+}	5.5	Ar-37	22.1	135.4^{+}	7.9
Ar-04	10.2	142.3	6.3	Ar-38	17.4	140.0	6.0
Ar-05	21.3	143.2	5.4	Ar-39	34.1^{+}	133.1^{+}	12.9^{++}
Ar-06	26.0	134.8^{+}	6.4	Ar-40	18.5	149.2	8.6
Ar-07	20.2	143.5	8.4	Ar-41	14.5	145.6	10.1^{+}
Ar-08	33.2^{+}	147.4	7.9	Ar-42	24.4	138.8	8.6
Ar-09	15.2	145.9	5.3	Ar-43	34.3^{+}	143.7	11.4^{+}
Ar-10	10.3	145.8	3.1	Ar-44	22.8	143.9	7.0
Ar-11	22.6	144.2	6.7	Ar-45	29.6	138.6	10.2^{+}
Ar-12	19.8	141.1	7.0	Ar-46	24.7	147.1	9.8^{+}
Ar-13	49.1^{++}	130.6^{+}	14.4^{++}	Ar-47	9.4	149.8	8.4
Ar-14	23.1	137.3	6.8	Ar-48	11.3	146.5	3.6
Ar-15	33.0^{+}	141.9	8.2	Ar-49	14.4	145.4	4.6
Ar-16	13.1	145.5	4.7	Ar-50	25.0	141.6	9.6
Ar-17	12.6	149.9	3.2	Ar-51	9.4	153.6	4.3
Ar-18	35.3^{+}	138.8	8.3	Ar-52	7.7	139.2	4.0
Ar-19	15.7	143.9	3.8	Ar-53	24.8	140.1	7.2
Ar-20	20.7	141.0	9.0	Ar-54	30.4	143.9	9.0
Ar-21	14.2	134.4^{+}	7.9	Ar-55	35.2^{+}	139.7	9.9^{+}
Ar-22	18.9	134.8^{+}	5.8	Ar-56	17.5	148.5	3.7
Ar-23	22.6	143.1	7.8	Ar-57	24.2	146.9	7.8
Ar-24	26.7	140.1	11.8^{+}	Ar-58	26.1	145.9	4.5
Ar-25	11.3	143.7	5.0	Ar-59	15.6	141.9	6.2
Ar-26	9.4	121.7^{++}	3.1	Ar-60	21.3	143.3	5.8
Ar-27	23.5	142.3	8.1	18-L2	46.9^{++}	125.3^{++}	10.2^{+}
Ar-28	21.9	139.1	5.4	19-L7	42.2^{++}	122.9^{++}	6.1
Ar-29	32.4^{+}	140.5	10.7^{+}	20-L5	38.9^{+}	141.3	10.6^{+}
Ar-30	28.5	138.6	6.0	19-L1	31.1	141.9	9.5
Ar-31	25.9	144.7	6.7	Mean	22.6	141.10	7.13
Ar-32	29.5	143.6	10.0^{+}	σ	9.2	6.00	2.61
Ar-33	15.5	137.5	5.6	Mean$\pm\sigma$	31.9	135.1	9.7
Ar-34	14.8	140.8	10.0^{+}	Mean$\pm 2.\sigma$	41.1	129.1	12.4

PP: pods per plant; DGH: days to green harvest maturity; YLD: yield (t ha^{-1}); $^{+}$ greater than $u+\sigma$; $^{++}$ greater than $u+2\sigma$.

effect, suggesting that varieties behave differently in different environments (Hadou el Hadj *et al*., 2022; Serafin-Andrzejewska *et al*., 2023).

It should be noted that PP, due to its demonstrated relationship with plant yield, allows for a strategy to select Faba bean genotypes with higher productivity, especially in the early stages of the breeding program, which aligns with the objectives of this study (Robsa *et al*., 2021; Hadou el Hadj *et al*., 2022; Ayenew *et al*., 2023).

Additionally, the existing genetic diversity associated with the phenology of Faba bean enables the identification of early-maturing genotypes. The goal for the study area is to concentrate the harvest in the second half of the year to increase production and provide rotation options for farmers in tropical highland regions (Álvarez-Sánchez *et al*., 2022).

For example, contrasting genotypes such as Ar-26 required 121.7 d from sowing to harvest, whereas genotype Ar-51 had an average of 153.6 d (Tab. 2). In practical terms, this means that the soil remains occupied for an additional 31.9 d, resulting in increased costs and heightened risks associated with biotic factors. Additionally, it is well known that legumes are highly sensitive to climate variations, particularly during prolonged drought periods, making shorter exposure times more advantageous (Serafin-Andrzejewska *et al*., 2023).

Table 2 shows that the group with statistical differences reported an average DGH of 130.3 d, which is lower than the range observed in Nariño for the regional variety Argentina, between 144 to 171.5 d, showing a gain in this attribute (Álvarez-Sánchez *et al*., 2022). This result is consistent when comparing this population with other regional Faba bean varieties such as Alpargata, Blanca común, or Roja, which reach up to 194 d to green harvest maturity (Álvarez *et al*., 2023).

El-Abssi *et al*. (2019) and Skovbjerg *et al*. (2023) report a predominance of dominance effects in controlling earliness in this species, suggesting that phenotypic selection could be an effective method to accelerate crop maturity.

Finally, although it has been noted that Faba bean yield should be analyzed with caution due to the crop's high sensitivity to environmental conditions (Derese, 2022; Hadou el Hadj *et al*., 2022), 11 genotypes were identified that exceeded the statistical threshold of one standard deviation above the mean, achieving a yield of 10.4 t ha^{-1}. Specifically, genotypes Ar-39 and Ar-13 reached yields of 12.9 and 14.4 t ha^{-1}, respectively, surpassing the general mean by two standard deviations (Tab. 2).

In the same region and production semester, genetic materials 18-L2, 19-L7, 20-L5, and 19-L1 exhibited an average yield of 19.7 t ha^{-1} (Álvarez-Sánchez *et al*., 2022), showing a reduction compared to the results presented in table 2. The most notable difference between studies was associated with fertilization (unpublished data), highlighting the lack of knowledge about crop nutrition and how this can influence genotype responses.

Although this study was conducted in a single reference location, further trials in multiple environments are necessary to validate the stability of the results. Nonetheless, the findings are promising when compared to crop statistics, as the selected genotypes exceeded both the estimated yield for the department of Nariño (9.0 t ha^{-1}) and the national average (4.3 t ha^{-1}) (MADR, 2022).

Moreover, it is noteworthy that this population outperformed various commercial varieties worldwide (Abou-Khater *et al*., 2022; Derese, 2022; Kindie and Nigusie, 2019; Robsa *et al*., 2021; Serafin-Andrzejewska *et al*., 2023). These results reinforce the potential of Faba beans in the high tropics, showcasing performance that surpasses regions traditionally associated with their center of origin.

This success is likely attributed to a combination of favorable environmental conditions, locally adapted agricultural practices, and the historical selection processes carried out by farmers.

Participatory selection (PS)

Half of the genotypes in the collection were selected in at least one criterion by a farmer, establishing a consistent pattern across different blocks (unpublished data). Therefore, it was considered that the PS method offers valuable feedback to the research, guiding material discrimination.

Participants were most interested in the production criterion, so the selection in the experimental plot focused on identifying the highest number, size, and maturity degree of pods of each genotype, consistent with farmers from Mexico and Ethiopia (Díaz-Bautista *et al*., 2008; Kindie and Nigusie, 2019; Robsa *et al*., 2021).

The genotypes Ar-13, Ar-39, Ar-45, and Ar-29 stood out by receiving 28 or more votes out of a maximum of 56 for this criterion, as shown in table 3, demonstrating a strong association with the variables YLD and PP (Tab. 2). This finding aligns with the conclusions of Kindie and Nigusie (2019), who emphasize that farmers can visually identify traits that enable them to estimate yield and recognize superior genotypes.

Table 3. Thirteen genotypes with the highest rating in the Participatory Selection process.

Genotype	Production	Plant architecture	Genotype health	PS
Ar-29	28^{+}	20	44	16.0
Ar-41	18^{+}	44	46	14.5
Ar-43	24^{+}	34	36	14.3
Ar-39	38^{++}	18	10	13.8
Ar-60	24	16	38	13.7
Ar-13	40^{++}	16	4	13.4
Ar-37	20^{+}	34	36	13.1
Ar-54	16	40	32	11.6
Ar-45	32^{+}	14	8	11.5
Ar-34	22^{+}	12	28	11.4
Ar-01	24	18	12	9.9
Ar-22	16^{+}	20	26	9.7
18-L2	16^{++}	20	24	9.4

Value corresponding to the sum of votes in four blocks; $^{+}$ Greater than $u+\sigma$ in PP/DGH/YLD; $^{++}$ greater than $u+2\sigma$ in PP/DGH/YLD.

However, among the genotypes that obtained the highest preference according to the production criterion, materials Ar-01 and Ar-60 exhibited only an average value in the agronomic evaluation (Tab. 2 and 3). This situation raised the question of an additional criterion supporting the given rating. The pod size identified by the farmers supported this decision due to its market implications, although it was not considered in the agronomic evaluation.

Regarding the architecture criterion, genotypes Ar-41, Ar-54, Ar-43 and Ar-37 stood out for their uniform and compact growth (Tab. 3). Farmers avoided selecting those with non-erect stems as they increase the likelihood of breaking due to the weight of the load, wind, or mechanical damage during cultural practices, characteristics that would not be evident if only plant height considered.

Genetic materials with similar characteristics to those identified in this study are confirmed by Derese (2022) and Skovbjerg *et al*. (2023), who have demonstrated that they can prevent yield losses by reducing phytosanitary problems in materials whose stems come into direct contact with the soil. Additionally, these authors identified that selecting low growth genotypes improves harvesting operations.

Plant health status, as the final criterion addressed with the farmers, played a significant role in refining the evaluated population, despite the experimental plot being managed under uniform phytosanitary conditions. Participants identified differences attributed to phytosanitary agents and color changes associated with plant vigor.

These observations align with findings by Díaz-Bautista *et al*. (2008), who associate such insights with the knowledge and skills of farmers, stemming from their daily interactions and cognitive processes developed through constant contact with the crop. In this regard, the materials with the highest votes were again related to high yield values, as evidenced in tables 2 and 3.

Identifying genotypes with enhanced health responses could serve as a valuable strategy to address key biotic challenges in Faba bean production (Ayenew *et al*., 2023). A prominent example is the ongoing effort to develop tolerance or resistance to chocolate spot disease caused by *B. fabae*, which has shown promising progress (El-Abssi *et al*., 2019; Hadou El Hadj *et al*., 2022). In this context, genotypes Ar-29, Ar-41, Ar-60, Ar-43, and Ar-37, which received more than 35 votes during the participatory selection process, emerged as standout performers in this study (Tab. 3).

Overall, it is important to highlight that the knowledge based on the skill acquired in managing the production system over the years expands the scope of technical expertise by adding elements of discussion and analysis that can only be addressed when working collaboratively (Fig 1.). In this case, the Farmer Score value was used as an essential element to calculate the selected fraction that will advance to a new evaluation process.

It is worth noting that this study did not consider significant aspects addressed in other research that could enhance future studies, such as the gender and age of farmers, as highlighted by Begna (2022). Similarly, culinary traits that could define a usage profile for Faba bean materials were not explored, as suggested by Mncwango *et al*. (2021) and Serafin-Andrzejewska *et al*. (2023).

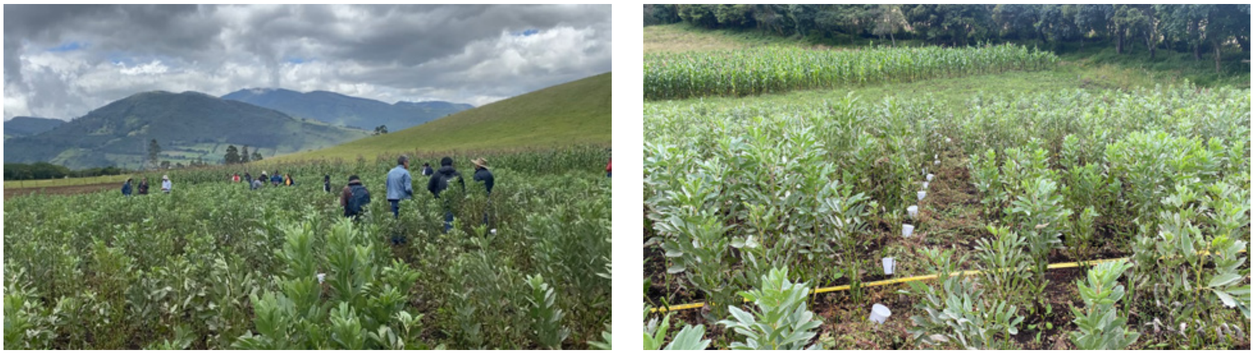

Figure 1. Participatory selection process with farmers (A), and experimental plot view (B).

Table 4. Thirteen genotypes with the highest rating using the Selection Index (SI).

Genotype	PP	DGH	YLD	FS	SI
Ar-13	49.1^{+}	130.6^{++}	14.4^{+}	13.4	2.45
Ar-39	34.1^{+}	133.1^{++}	12.9^{+}	13.8	1.90
18-L2	46.9^{++}	125.3^{+}	10.2^{++}	9.4	1.58
Ar-29	32.4^{+}	140.5^{+}	10.7	16	1.58
Ar-43	34.3^{+}	143.7^{+}	11.4	14.3	1.47
Ar-45	29.6	138.6^{+}	10.2	11.5	1.07
Ar-55	35.2^{+}	139.7^{+}	9.9	8.7	0.85
Ar-41	14.5	145.6^{+}	10.1	14.5	0.83
Ar-37	22.1	135.4	7.9^{+}	13.1	0.82
Ar-54	30.4	143.9	9.0	11.6	0.79
Ar-34	14.8	140.8^{+}	10.0	11.4	0.65
20-L5	38.9^{+}	141.3^{+}	10.6	5.0	0.64
19-L7	42.2^{++}	122.9	6.1^{++}	5.0	0.55
$\hat{y}s$	32.65	137.03	10.26	11.36	
S	10.76	7.16	2.05	3.48	
μg	20.25	141.11	7.13	6.78	
σg	9.21	6.00	2.52	3.17	
DS	12.40	-4.08	3.13	4.58	

PP: pods per plant; DGH: days to green harvest maturity; YLD: yield; FS: farmer score; $\hat{y}s$: mean of the selected fraction; DS: standard deviation of the selected fraction; μg: general mean of the 64 Faba bean genotypes; σg: standard deviation of the 64 Faba bean genotypes; DS: differential selection ($\hat{y}s$ - μg); $^{+}$ Greater than $\mu + \sigma$; $^{++}$ Greater than $\mu + 2\sigma$.

Selection index

Using the criteria assigned to the SI and under pressure of 20%, the selected population exhibited gains relative to the initial population of 64 Faba bean genotypes, showing increases of 61.2% for PP, 43.8% for YLD, and 67.8% for FS (Tab. 4). These results highlight the potential for further exploring selection gains within this newly formed population through evaluations across multiple environments, possibly advancing to a fifth growing cycle since the initial collection.

Table 4 illustrates that the final thirteen genotypes achieved an average of 32.65 pods per plant and an experimental yield of 10.26 t ha^{-1}, indicating superior agronomic performance. Additionally, the average farmer score of 11.36 units for these genotypes underscores their preference among potential users.

The outlook is more conservative for the DGH variable, which showed a gain of only 2.9% when comparing the selected population with the initial one (Tab. 4). This suggests that this phenological trait may be approaching a point of stability, implying that selection gains could be smaller in subsequent cycles (Lagos *et al*., 2020). This observation aligns with the findings of El-Abssi *et al*. (2019) and Skovbjerg *et al*. (2023), who suggest that direct selection for this trait may yield rapid but limited improvements.

The theoretical basis for using the SI indicates that focusing solely on yield as a trait for selecting a population does not ensure improvements in another significant trait that may or may not be associated (Brown *et al*., 2020). However, the literature review did not reveal studies in this species that concentrate agronomic and farmer selection variables into a final index.

In the best case, the SI process considers, and the interaction generated between technicians and farmers is highlighted (Mncwango *et al*., 2021; Robsa *et al*., 2021; Begna, 2022; Ayenew *et al*., 2023). However, it is not evident how farmer input was selected for the final genotypes, as done in this study, where a unique index was built to form the population advancing to the next study stage.

Finally, it is noted that the thirteen selected genetic materials have high potential to be tested in multiple environments, selected for specific traits, or used in hybridization strategies to increase genetic variability and thus expand selection opportunities. This provides a continuous and effective response to the environmental and socioeconomic challenges facing Faba bean cultivation in southern Colombia.

CONCLUSION

The results highlight the importance of participatory work with farmers to develop genotype evaluation strategies for Faba beans, demonstrating a high correlation between subjective preferences and studied agronomic traits, significantly expanding the selection possibilities.

The thirteen selected Faba bean materials showed promising results with average values of 32.65 pods, 137.03 days to green harvest maturity, and 10.26 t ha^{-1}, showing gains compared to the original population. Additionally, the Participatory Selection included in the Selection Index increased by 4.58 units, reaffirming the participatory process used.

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