Amhara Agricultural Research Institute (ARARI)
Socio-Economics and Agricultural Extension Research Directorate

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On-Farm Demonstration of Faba Bean Parasitic Weed (*Orobanche Crenata*) Management Options in South Gondar Zone, Ethiopia

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Abstract

Faba bean is an important pulse crop in area coverage and volume of annual production in Ethiopia. However, the productivity is still far below its potential mainly due to biotic factors. Faba bean parasitic weed (*Orobanche crenata*) is the main biotic factor in Tach Gayint woreda. Therefore, this demonstration was conducted to evaluate and demonstrate the integrated faba bean parasitic weed management options of using a combination of Glyphosate herbicide and the partially resistant "Hashange" faba bean variety. The treatment arrangement was designed in a simple plot considering farmers as replications. Foliar application of Glyphosate herbicides were used at a rate of 0.30 litter ha^{-1} diluted with 300 litter water ha^{-1}. The result revealed that the highest grain yield of 2.875 tons ha^{-1} was obtained from a sprayed plot of the partial resistant variety and had an overall yield advantage of 31.40% over the unsprayed partial resistant Hashenge variety under the existing practice. Besides, the highest final faba bean yield the parasitic weed count was zero per hectare in sprayed plot, but 647,500 parasitic weed numbers (number of Orobanchae per ha^{-1}) were recorded from the unsprayed control plots. The results of this study suggested that the proper application of Glyphosate herbicide combined with partially resistant Hashenge variety is important for the economic management of faba bean parasitic weed (Orobanche). The partially resistant Hashenge variety that was twice spayed with the 300mlha^{-1} glyphosate herbicide yielded the highest net benefit (144,625 ETB ha^{-1}). In contrast, the unsprayed partially resistant Hashenge variety (control plot) yielded the lowest net benefit (46,027.5 ETB ha^{-1}). Therefore, the integration of Hashenge faba bean variety and two times spray of 300ml ha^{-1} glyphosate should be pre-scaled up broadly in Orobanche prevalent areas of the region.

Keywords: Faba Bean, Glyphosate, Hashenge, Orobanche, Parasitic Weed

Introduction

Faba bean (*Vicia faba* L.) is also known as broad bean, horse bean, and field bean, and it is the world's fourth most significant pulse crop (Siyum *et al*., 2022) after chickpeas, lentils, and peas. Among the highland pulses, faba bean is the most significant in terms of area, productivity, and food supply in

Ethiopia. According to NPVCDSE (2015), for smallholders, pulses are a more cost-effective protein source than meat, fish, and dairy products and for the 40% of Ethiopians who identify as orthodox Christians, pulses are also a significant source of protein during the fasting season. It is an important crop in the cropping system, where it is produced in rotation with cereals and oil crops to improve soil fertility and as a break crop against soil-borne diseases (Akalu and Mekonnen, 2021; Degago, 2000). Overall, the country's pulse productivity is hampered by a variety of biotic and abiotic challenges, including diseases, parasitic weeds, a lack of better varieties, and a scarcity of certified seeds. The new faba bean gall disease and Orobanche parasitic weed have caused faba bean production in the Amhara region to gradually decline below its potential, making it unable to meet the growing local demand for seeds and consumptions (Bitew & Tigabie, 2016; Misganaw, 2016).

According to Takele *et al.* (2022) and Misganaw (2016), *Orobanche crenata* Forskal, often known as Crenate Broomrape, is a member of the Orobanchaceae family. It is a root holophrastic weed that has no chlorophyll and depends only on host plants to flourish. In severely infected drier and warmer regions of the world, this parasite significantly infects plant species belonging to the families Leguminosae, Apiaceae, and Asteraceae. It is well known for endangering subsistence farmers' livelihoods and having disastrous impacts on cool-season food legumes, particularly faba beans (*Vicia faba* L.). Crops with parasitic weeds might lose up to 100% of their yield, depending on the severity of the infection. With its many tiny seeds that may be readily dispersed by a variety of methods and survive in the soil for up to 20 years, the parasite's long-term impacts are far more severe than its short-term ones (Takele *et al*., 2022).

Currently, faba bean producing areas in the region, specifically the south Wollo, south Gondar, and north Shoa zones are suffering from faba bean gall disease and Orobanche weed invasion, resulting in the loss of locally cultivated varieties from production. In recent years, regional research initiatives have been conducted to boost pulse productivity. This has resulted in promising results in minimizing production constraints in the region, notably faba bean gall disease and Orobancea parasitic weed. Management options for faba bean parasitic weed (*Orobanche crenata*) have been identified, demonstrated, and scaled up by farmers (Kassaw *et al*., 2022; Misganaw, 2016; Siyum *et al*., 2022). In addition to the aforementioned measures, there are still gaps in sustaining pulse production and having a larger influence on yield. Knowledge of farmers' and agriculture professionals' on the integrated management of parasitic weeds is poor in the faba bean production areas of the Amhara region. As a result, the plant health initiative (PHI) in International Center of Agricultural Research in Dry Areas (ICARDA) was planned to create awareness for farmers and development agents with training, demonstrations of results, technologies, and scaling up of proven technologies. Therefore, it is vital to demonstrate faba bean

parasitic weed (Orobanche) management options on faba bean in major faba bean growing areas of the south Gonder zone. The main aim was to provide farmers with a menu of available parasitic weed resistant improved faba bean variety-Hashenge and glyphosate herbicide for faba bean parasitic weed (Orobanche) management options and to assess farmers and extension workers reactions.

Materials and Methods

Description of the study area

Tach Gayint woreda is located in the south Gondar zone of the Amhara region of Ethiopia. Tach Gayint is bordered on the South by the Bashilo River, which separates it from the south Wollo zone, on the West by Simada woreda, on the north by Lay Gayint woreda, and on the East by the Checheho River, which separates it from the north Wollo zone. The woreda is located 200km north-east of the regional capital city, Bahir Dar. Tach Gayint woreda lies between 110 22' - 110 4' N latitude and 280 19'-280 43' E longitudes. It has an altitude range of 1500-2800masl. The mean minimum and maximum annual temperature range from 13oc to 27oc. The mean annual rainfall ranges from 900 to 1000mm per annum. There are three agro-ecological zones in the *Woreda*, namely-kola (tropical) which covers 23.50%, Woina Dega (subtropical) which covers 63.50%, and Dega (temperate) which covers 13%. The *Woreda* has 15 rural Kebeles and one town: Arib Gebeya. The *Woreda* is characterized by an erratic rainfall pattern, with rainfall distributed over the growing season (mid-June to end-September) (District Agricultural Office, 2020). The district is known for its potential in teff and faba bean production. The production system in the study area is a mixed crop livestock agricultural system whereby smallholder farmers practice crop and livestock production (Mekuria and Mekonnen, 2018).

The treatments and design

On-farm comparative evaluation of different faba bean production technologies was done in the 2022/23 growing season in a participatory approach, the treatments were: one partially resistant faba bean variety named as Hashenge, integrated with two times foliar spray of reduced rate of glyphosate (0.30 litter ha^{-1}) at early flowering stage in comparison with the partially resistant faba bean variety, Hashenge without glyphosate spray (control). The treatment arrangement was designed as an un-replicated simple plot considering farmers as replications. The experiment was replicated on 6 progressive farmers' plots that were selected purposely based on the infestation level of the parasitic weed.

Input use and field management practices applied

A seed rate of 150 kg ha^{-1} was used and planted in rows with the spacing of 40cm and 20cm between rows and plant, respectively. A fertilizer rate of 121 kg ha^{-1} NPS (nitrogen, phosphorous, and sulfur) was used. The whole recommended amount of NPS fertilizer was applied during planting. The sowing date was done from July 5-10, 2022. The field was hand weeded two times and two times with glyphosate herbicide spray starting from the flowering stage of the faba bean and the second spray was after 15 days.

(A) (B)

Figure 1: Sowing time (A), and chemical spray (B), 2022

The partially resistant variety (Hashenge) without any treatment was compared with the under full package utilization to display differences achieved through the partially resistant varieties (Hashenge) combined with two times a spray at a reduced rate of Glyphosate herbicide. Besides, Hashenge without any treatment was managed in full package and farmers‟ prevailing practice to show changes attained due to reduced herbicide spray, keeping the variety constant.

Extension research approaches

A participant research approach was used in demonstrating faba bean technologies. Farmers research extension groups (FREGs) approaches were established and used to enhance stakeholder's engagement in problem identification, joint planning, implementation and monitoring and evaluation events. The establishment was done based on (JICA/EIAR, 2015; Anchala, 2008). FREG was organized consisting of 26 (5 female) members to enhance participatory evaluation who have common problems and are interested in working in groups in collaboration with research, extension, and other non-public organizations in the process of technology generation, verification, demonstration, and improvement (JICA/EIAR, 2015). Moreover, for easy communication and facilitation, farmers were able to organize

themselves, by selecting their chairperson and secretary after discussions with a multidisciplinary team of researchers and extension workers.

The purpose of utilizing FREGs is to engage farmers in the research process and strengthen the link between farmer's needs and research outcomes (Probst *et al*., 2003). Technology evaluations of the demonstrations were done by farmer's research extension groups (FREGs) with the facilitation of researchers and extension agents. At Tach Gayint, two FREGs were formed and were reorganized, which comprised 25 farmers and participated throughout the process of the activities. Subgroups were formed separately based on sex, age, and education, with 5–6 members enhancing the dominance/imposition of some farmers' ideas or perceptions on others, which enhances the participation of all farmers. Evaluations were carried out at the vegetative and mature stage of the crop and farmers were able to identify evaluation criteria based on their own experiences related to faba bean production. The criteria were ranked and prioritized in order of their importance using the pair-wise ranking method.

The evaluations were focused on two weed management technologies (the resistant variety and chemical management methods) by using direct scoring methods (1= the best and 2 = the least). The scores were given to each treatment with each criterion, and thus group results were added together and ranked in ascending order for both locations and finally the lowest sum gives the best scores). The sum of preference value (score x weight) of each treatment across all criteria was used to determine the final acceptability rank among the treatments in each location. Furthermore, Spearman's rank correlation coefficient (rs) was used. The correlation coefficient was calculated using the following formula;

$$\mathrm{rs} = 1 - \frac{6\sum d2}{n(n2-1)}$$

where, n denotes number of individuals or phenomena ranked (number of varieties in this case) and d denotes difference in the ranks assigned to the same individual or phenomenon (actual yield rank minus farmers preference rank).

Joint monitoring and evaluation

The target of participatory technology evaluation and demonstration is not only maximizing yield but also to improve actors' involvement in selecting technologies. Therefore, both teams of researchers, district agricultural experts, kebele development agents, and farmers were jointly and separately monitor and evaluate the technology. During monitoring and evaluation, technology implementations in terms of agronomic practices, Orobanche parasitic weed management and constraints of the stakeholders were assessed and corrective actions were taken for further improvement.

Types and methods of data collection

Qualitative and quantitative data types were collected. Yield data were collected after crop harvest and farmers' and experts' feedbacks were collected during monitoring and evaluation and technologies evaluation events at the crop vegetative and maturity stages.

Data analysis

Descriptive statistics such as mean, maximum, minimum, percentage and social data (farmers' and experts' opinion/feedbacks) were qualitatively described. Partial budget analysis of the treatment was calculated (CIMMYT, 1988). Besides these; the technological and extension gaps and the technological index among treatments were analysed (Geneti *et al*., 2017; Mihretu *et al*., 2019). Descriptive statistics were analysed by using SPSS and analysis of variance (ANOVA) was done.

Capacity building of stakeholders

Capacity building plays an important role in solving the existing farming problems in the study area. Capacity building also involves creating awareness about the new technology and improving variety and ways of doing things for technology users. The final outputs of the capacity building create a wider demand for the new technology, its variety and ways of doing things for the end-users of the technology. Training was given with team researchers (extension, agronomists, breeders and protection) about full production packages' Faba Bean technologies. The farmers' indigenous knowledge is raised during training time, such as crop protection, organic fertilizer, hand weeding, and Parasitic weed control. Faba bean are a commercial crop, so we can solve the foreign currency shortage at the country level by supplying the Faba bean product to the foreign market at the international level in the world.

Table 1: Training participant and stakeholders.

Participant	Lay Gayint		Tach Gayint		Total
	Male	Female	Male	Female	
District Expert	4	0	4	0	8
Kebele Expert	1	2	2	1	6
Farmers	21	9	21	9	60
Total	26	11	27	10	74

Figure 2. Photos of the training participant

Field day and promotion

At the end of the trial, field days were organized involving model farmers, development agents, and farmers from the trial sites, experts from two other potential districts, unions, local NGOs, and administrative officials. Field day has a vital role in the technology diffusion and adoption process to popularize new technologies and innovations on a wider scale easily to end-users. The field day program includes field visits, experience sharing, and detailed discussions on the demonstration technologies. A total of 110 (16 female) participants visited the trial and applauded the partial resistant Hashenge variety for its good growing performance. Also, participants during the field visit confirmed that Glyphosate is effective in controlling Faba bean parasitic weed (Orobanche) management (Figure 1).

Results and Discussion

Farmers' technologies preference evaluation

Farmers were identifying the selection criteria to select the best faba bean parasitic weed control methods during evaluation events (Figure 3).

Figure 3: Farmers at evaluation events at Tach Gayint district

During evaluations, female farmers focused on consumption needs than the productivity crop attributes of faba bean. The results from the pair-wise ranking matrix showed that evaluators gave great emphasis towards faba bean parasitic weed especially Faba bean parasitic weed and number of weed per plot followed by the number of seed per pod, earliness, and tiller capacity in both locations as shown below.

Table 2: Pair wise ranking of farmers' selected traits of faba bean parasitic weed control treatments

Traits	NOPP	NOPPP	WR	TC	SPP	Total	Rank
NOPP	X	NOPP	WR	NOPP	NOPP	3	2nd
NOPPP		X	WR	NOPPP	NOPPP	2	3rd
WR			X	WR	WR	4	1st
TC				X	TC	1	4th
SPP					X	0	5th

Notes: *NOPP = number of Orobanche per plot, NOPPP = number of pod per plant, WR = weed resistance, TC = Tiller capacity, SPP = seed per pod.*

The results from the pair-wise ranking matrix showed that evaluators gave great emphasis towards parasitic weed resistance especially Orobanche and less parasitic weed followed by the number of seed per plant and tiller capacity in both locations as shown.

Table 3: Ranking of faba bean Orobanche weed management treatments by farmer's selection

Treatment Arrangement	Selection criteria's					Total	Rank
	WR	NOPPP	TC	NOPP	SPP		
Hashenge with Glyphosate	17	17	17	17	17	85	1st
Hashenge without Glyphosate	58	58	58	58	58	290	2nd

Notes: NOPP = number of Orobanche per plot, NOPPP = number of pod per plant, WR = weed resistance, TC = Tiller capacity, SPP = seed per pod

Table 4 Matrix ranking of treatments weighted (*score = trait rank*treatment rank*)

Treatments	Weighted score of Treatments					Total Score	Rank
	WR (1)	NOPPP (2)	TC (3)	NOPP (4)	SPP (5)		
Hshenge with Glyphosate	17(1)	17(2)	17(3)	17(4)	17(5)	85	1st
Hashenge without Glyphosate	58(1)	58(2)	58(3)	58(4)	58(5)	1160	2nd

Notes: Number of Orobanche per plot, NOPPP = number of pod per plant, WR = weed resistance, TC = Tiller capacity, SPP = seed per pod, Scores given (1, 2, 1 = the best)

The score was multiplied by the respective weights which present the overall preferences of the technologies and thus, the results were aggregated for final decision and ordering (the least sum was

ranked 1st) (Russell, 1997). Generally, by the selection traits, a partially resistant improved variety with Glyphosate spray was selected first to others.

Table 5. Field day participants

Participant	Male	Female	Total
Farmers	25	4	29
Kebele extension workers	54	41	95
Zonal & district Level decision makers	5	1	6
Zone and district Expert	11	2	13
Researchers	15	1	16
Total	110	49	159

Biological yield of faba bean

Sample biomass and grain yield data were taken from each participant farmers and treatments. Representative samples from each treatment were taken using "x" techniques and added the result that gives the average yield of the treatment. Finally, all sites of the same treatment were added to decide the average yield per hectare based on each site. As the demonstration study yield result showed that the partially resistant variety, Hashenge, yield can be improved when it is supported with the integration of two time's spray of 0.30 litter ha^{-1} of glyphosate. Two times, glyphosate spray on Hashenge variety was given the highest mean grain yield of (2875 kg ha^{-1}). Precisely, the partially resistant Hashenge variety with two time's spray of reduced rate (0.30 litter ha^{-1}) of glyphosate had a yield advantage of 218.50% over the unsprayed partially resistant Hashenge variety (control). Similarly, the highest biomass yield (straw yield) (6.50 ton ha^{-1}), was found on the integration of Hashenge variety and two times sprayed of glyphosate herbicide as compared with Hashenge without glyphosate spray (3.50 ton ha^{-1}).

Table 6: Average grain yield (ton/ha) and other parameters at each farm plots, 2022/23

Treatment	PH(cm)	PPP	SPP	Stand (count/ha)	NO/ha	Owgt (t/ha)	DB (t/ha)	GY (t/ha)	Yad (%)	Rank
HG	133.7	21.5	2.79	160,000	0	0.00	6.5	2.875	218.5%	1st
HWG (control)	123.3	6.7	1.76	25,825	647,500	1.52	3.5	0.9025		2nd

Notes: *Foot note*: *PH = plant height, PPP = pod per plant, SPP = seed per pod, NO/ha = Number of Orobanche per hectare, Owgt = Orobanche weight, DB = Dry biomass, GY = Grain yield, Yad = Yield advantage, HG = Hashenge with glyphosate spray, HWG = Hashenge without glyphosate spray*

Farmers' preference versus actual yield comparison

Spearman's rank correlation coefficient; "rs can be used to see the degree of coincidence between the farmer's preference ranks with the actual grain yield rank of each treatment and then expressed in percentage (Ferdous et al., 2016) as shown below in Table 7.

Table 7: Farmers" preference value and actual yield comparison of technologies, 2022/23

No	Treatment	Tach Gayint		
		Preference value	Actual yield	D^2
1	HG	1	1	$(1-1)^2$
2	HWG (Control)	2	2	$(2-2)^2$
Spearman's rank correlation coefficient for both locations, Rs =1(100%)				

Notes: HG = Hashenge with glyphosate spray, HWG = Hashenge without glyphosate spray

$$\sum D^2 = (1-1)^2 + (2-2)2 = 0; Rs = 1 - 6\frac{\sum 2^2}{2(2^2-1)}1 - \frac{6\sum D^2}{n(n^2-1)} = 0, \quad rs = 1 - 0 = 1$$

The correlation coefficient, "rs" showed the degree of coincidence between farmers' preference rank and actual yield obtained for both site were about 100%. The participant farmers preferred the integration of improved faba bean variety (Hashenge) and sub lethal dose of glyphosate herbicide (300mlha^{-1}). This indicates that farmers' preference and actual yield obtained have good correlation (above 50%).

Partial budget analysis

The partial budget analysis was carried out by the procedures of CIMMYT (1988) based on the assessment of financial returns in this study indicated that using a combination of improved variety and herbicide application for faba bean parasitic weed management was profitable (Table 8). The highest net benefit of 144,625 ETB ha^{-1} was obtained from a partially resistant Hashenge variety two times spayed with glyphosate herbicide. On the other hand, the lowest net benefit (46,027.5 ETB ha^{-1}) was obtained from the unsprayed partial resistant Hashenge verity (control plot).

Table 8: Partial budget analysis of different treatments

	Treatment 1	Treatment 2
Ost of inputs		
Glyphoset (Price Birr (liter/ha))	450	0
Total input costs	450	0
Total labor costs	300	300
Total variable cost = (TMC + TLC)	750	300
Gross revenue		
Average yield (kg/ha)	2875	902.5
Average farm gate unit price Birr/kg	51	51
Gross income (1x2)	146,625	46027.5
Gross margin per hectare (GI – TVC)	145,875	45,727.5
Returns on investment/ha (GM/TVC)	193.5	152.4

Generally, the comparative advantage of the technology was very high with a marginal rate of return on investment per hectare, which is 193.50 times more than 152.40 for unsprayed partial resistant Hashenge variety, which means 100,147.50 Ethiopian Birr (ETB) per hectare were gained as compared with unsprayed Hashenge variety production in the Orobanche prevalent areas as shown in the above (Table 8). The contribution of this new technology (the integration of resistant variety and sub-lethal dose of glyphosate herbicide) enhances faba bean yield and this also has high contribution for the nutrition and food security of the community in the parasitic weed prevalent areas of Amhara region.

Conclusion and Recommendations

Faba bean parasitic weed (Orobanche) is the major and most destructive parasitic weed in Tach Gaint woreda of South Gondar Zone. The results revealed that the highest final faba bean parasitic weed percent severity of 100% was recorded from unsprayed control plots. Using a combination of improved Hashenge variety with a reduced rate of glyphosate herbicide foliar spray at the flowering stage, the faba bean reduced the severity of the parasitic weed by 100% as compared with the unsprayed and the highest grain yield of 2.875 tons ha^{-1} was obtained from the treated plot. However, the Hashenge variety without glyphosate spray gives a grain yield of 0.9025 tons ha^{-1} under the existing practice.

Most of the respondents agreed and approved that the Hashenge variety with two times glyphosate spray had good tiller capacity; resisted parasitic weed (Orobanche) infestation, and high yielders as compared to the unsprayed Hashenge variety. Moreover, almost all the participants strongly agreed on the

effectiveness of glyphosate herbicide, and they have decided to use the herbicide by the next production season. The woreda agricultural office should provide the herbicide based on farmers demand assessment. Similarly, based on the partial budget analysis result, the highest (31.50%) marginal rate of return was obtained from the Hashenge variety with two times sprays of glyphosate herbicide. The results of this study suggested that the proper application of glyphosate herbicide combined with improved resistant varieties is important for the economic management of the faba bean parasitic weed (Orobanche). Therefore, it is recommended that, this technology should be pre-scaled up on the broadly clustered platforms on the parasitic weed (Orobanche) prevalent areas in the next production seasons.

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