Participatory evaluation of faba bean gall disease (*Olpidium viciae*) management options in the highland disease hotspot areas of South-Eastern Amhara Region, Ethiopia: An integrated approach

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Participatory evaluation of faba bean gall disease (*Olpidium viciae*) management options in the highland disease hotspot areas of South-Eastern Amhara Region, Ethiopia: An integrated approach

Yehuala Kassa¹*, Teklemariam Ayele¹, Yifru Worku¹ and Beneberu Teferra¹

**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 the emerging faba bean gall disease. This study, therefore, aimed to evaluate and demonstrate the integrated disease management options of using a combination of Noble 25 WP fungicide and moderately disease-resistant varieties. The treatment arrangement was designed as an un-replicated simple block considering farmers as replications. Foliar application of Noble 25 WP fungicide was used at a rate of 1 kg ha⁻¹ using 400 l ha⁻¹ water. The agronomic, economic, and farmer preference data were collected and analyzed in descriptive statistics. The result revealed that the highest grain yield of 3.96 tons ha⁻¹ was obtained from a sprayed plot of Gora variety and had an overall yield advantage of 130.8% over farmers’ unsprayed local variety under the existing practice. Besides, the highest final faba bean gall disease percent severity of 45.6% was recorded from the unsprayed control plots. Using a combination of Gora improved variety with foliar application of the fungicide reduced the severity of the disease by 59.3% compared with that of the sprayed local variety. Similarly based on the partial budget analysis result, the highest (783.8%) marginal rate of return was obtained from the use of...
Gora variety with three times sprays of Noble 25 WP. The results of this study suggested that the proper application of fungicides combined with improved varieties is important for the economic management of faba bean gall disease.

**Subjects:** Environmental Sciences; Agriculture and Food; Agronomy

**Keywords:** Faba bean gall; Noble 25 WP fungicide; Gora variety; Dosha variety; integrated options

1. **Introduction**

Faba bean (*Vicia faba* L.) is the first largest produced food legume globally (Gaur et al., 2010) and the country is the second-largest producer of faba bean in the world next to China (Abebe et al., 2014; Ronner & Giller, 2012). In Ethiopia, faba bean is an important pulse crop in terms of area coverage and volume of annual production (CSA, 2018b; Hailu et al., 2014). It accounts for 30.9% of annual pulse production (CSA, 2018a) and it is a multi-purpose legume and leading protein source for the rural people in Ethiopia (Emiola & Gous, 2011; Malunga et al., 2014; Sarker et al., 2014). As a potential rotational crop, it plays an important role in soil fertility improvement through nitrogen fixation (Agegnehu & Fessehaie, 2006; Ronner & Giller, 2012). Most importantly, it has been serving as a source of foreign currency to the country (Rashid et al., 2010; Thijis et al., 2015).

Despite its huge importance and area coverage, the productivity of faba bean is about 2.1 tons ha⁻¹ (CSA, 2018a), far below the potential of the crop which was 5.2 tons ha⁻¹ (MoARD, 2008). Various biotic and abiotic factors have attributed to the low productivity of the crop. Of which, the use of old and low yielding local variety and unavailability of high yielder improved varieties (Alene et al., 2000; Anteneh et al., 2018; Bishaw & Van Gastel, 2008; Dadi et al., 2005; ICARDA, 2008; Rashid et al., 2010) limited or no use of inorganic fertilizers (Asfaw et al., 2011) and the newly emerged faba bean gall disease (Anteneh et al., 2018; Bitew, 2015; Bitew & Tigabe, 2016; Debela et al., 2017; Hailu et al., 2014) might have been the most important factors.

There are diseases that affect faba bean in terms of yield and quality, but only a few of them, i.e. chocolate spot (*Botrytis fabae* Sard.), rust (*Uromyces Vicia fabae*), black root rot (*Fusarium solani*), and foot rot (*Fusarium avenaceum*) are among fungal groups that contribute to the low productivity of the crop. On top of the above, recently, faba bean production has been constrained by a new emerging disease known as faba bean gall caused by *Olpidium viciae* (Kusano) that causes up to complete crop failure in susceptible cultivars and under conducive prevailing conditions (Abebe et al., 2018, 2014; Hailu et al., 2014; Wondwosen et al., 2019b, 2019c; Yitayih & Azmeraw, 2017). The production of the crop is highly challenged and farmers are frustrated by the nature of the disease and thus cultivation of faba bean by smallholder farmers is diminishing in the country. For this disease in the country, no sound control measure has been investigated yet, except the limited recommendations by (Abebe et al., 2018; Alehegn et al., 2018; Bitew & Tigabe, 2016; Hailemariam et al., 2017; Wondwosen et al., 2019b, 2019a; Yitayih & Azmeraw, 2017).

Currently, different attempts have been made for control of complex faba bean gall disease including fungicide sprays. Application of fungicide like Bayleton 25 WP (*Traidimefon*) (Abebe et al., 2018; Bitew & Tigabe, 2016; Hailemariam et al., 2017) and Redomil Gold MZ 68 WG (*Metalaxil-M40 g/kg +Macoze 640 g/kg*) (Abebe et al., 2018; Bitew & Tigabe, 2016; Wondwosen et al., 2019b) were significantly reduced faba bean gall disease. Besides the improved variety including Dasha, Gora, and Gachen was identified as moderately resistant to this disease (Alehegn et al., 2018; Wondwosen et al., 2019a). Moreover, many of the existing literatures agreed that faba bean gall disease can be minimized to an acceptable level by using a combination of improved varieties protected by three to four-time foliar application of fungicides (Alemu & Tadele, 2017).

Despite such efforts have been made to improve production and productivity of the crop through minimizing the effect of the disease, the majority of the rural smallholder farmers were still largely
depending on their traditional growing practices, which explained by the low level of adoption of the improved technologies. This is mainly due to the fact that agricultural technology development and verification processes were initiated and implemented solely by researchers’ and the end-user farmers were a merely passive observant. In contrast, a participative approach uses existing local skills and knowledge as a starting point, and is built around a process that enables the farmers to control and direct research and development of technologies that meet needs prioritized by farmers themselves (Abbeam et al., 2018; Suvedi et al., 2017). Recently, there has been a great deal of attention devoted to the notion of farmer participation in agricultural research. One of the reasons for advocating farmer involvement in the research process is that farmers are more aware of their problems than outsiders and hence are in a better position to evaluate and identify the technologies best suit to their existing situations. The involvement of farmers would increase the relevance of research outcomes in the field and could enhance the acceptability of the technology developed. Many of the previous studies pointed out that farmers, who participated in on-farm trials, demonstration, farmer research groups, and field day events adopted improved agricultural technologies more than others did (Asfaw et al., 2011; Chandio & Yuansheng, 2018; Dadi et al., 2005; Krishnan & Patnam, 2014; Verkaart et al., 2017). Hence, this study is initiated to evaluate and promote the integrated faba bean gall disease management options using fungicides and moderately resistant faba bean varieties and to assess the technology preference of the smallholder farmers and experts.

2. Materials and methods

2.1. Characterization of the experimental site

The study was conducted at Basona Werana district of North Shewa zone Amhara region in 2019 main growing season. The district is located about 130 km north of Addis Ababa between 9°49’59.99” North latitude and 39°19’ 60.00” East longitude. The district is known for its potential in faba bean production. Agro-ecologically most of the area in the district is classified under moist Dega with altitude ranges between 2800–3000masl while annual temperature varies from 9° to 15° C. Topographically the district is mostly mountainous with escarpments covered predominantly with reddish-brown soil type. The mean annual rainfall ranges from 900 to 1500 mm. The production system in the study area is a mixed-crop livestock agricultural system whereby smallholder farmers practice crop and livestock production.

2.2. Materials and research design

On-farm comparative evaluation of different faba bean production technologies was done in 2019/20 growing season in a participatory approach. Two improved faba bean varieties, i.e. Gora and Doshia varieties were used integrated with foliar application of Noble 25 WP (Triadimefon) fungicide. The treatment arrangement was designed as an un-replicated simple block considering farmers as replications. The experiment was replicated on 20 progressive farmers’ farm plots that were selected purposively based on their interest in receiving the new technologies. A seed rate of 200 kg ha⁻¹ for the local variety and 275 kg ha⁻¹ for Doshia and Gora varieties were applied. The three faba bean varieties were distributed randomly to the selected farmers. Foliar application of Noble 25 WP was used at a rate of 1 kg ha⁻¹ using 400 l ha⁻¹ water for one-time spray. The first spray was started early from the first appearance of the disease and sprayed three times with 10-days interval. All the rest agronomic practices were applied based on the recommendation. The improved varieties were compared with the local cultivar under full package utilization to display differences achieved through improved varieties combined with the recommended fungicide for faba bean gall disease pathogen, keeping package components constant. Besides, the local variety was managed in full package and farmers’ prevailing practice and without fungicide to show changes attained due to fungicide spray, keeping the variety constant.

Farmers’ research and extension group (FREG) was organized consisting of 23 (3 female) members to enhance participatory evaluation. The group members were selected in consultation with development agents to represent different social segments of the community. The groups
had chairman and secretary to facilitate the FREG tasks as well as they had an action plan and meeting schedule for evaluating the experiment following the physiological growth stages. Trial plots were for free, while the research center covered other experimental costs. Before the implementation of the trials, all FREG members were trained on the basic agronomic practices and technology package components embracing both theoretical and practical sections. FREG members were conducting more than four times field trial performance evaluation.

2.3. Data collected
Both quantitative and qualitative data were collected from trial plots and participant farmers using a checklist and focus group discussions (FGDs). Secondary data were collected from different published and unpublished sources. Agronomic data including plant height, grain and biomass yield, and disease score were collected on a pilot basis. Farmers’ reaction and preference to each variety and about the sprayed fungicide were collected through probing of FREG members. Farmers, therefore, brainstormed to identify their main evaluation criteria to be considered in evaluating the improved faba bean varieties under local context. Tillering capacity, disease resistance, resistance to waterlogging, adaptation to the area, number of pods per plant, number of seeds per pod, seed size, early pod setting, flower abortion, early maturity, and grain yield were considered by farmers during evaluation. Economic data (production costs and benefits) were collected to compare the cost-effectiveness of treatments.

2.4. Data analysis
Faba bean gall incidence and severity assessments were collected from randomly selected plants starting from the onset of the first gall symptoms at a stage of 4–6 leaves every 10-days interval during spraying. The incidence of faba bean gall was determined from the ratio of the number of infected plants to the total plants assessed in a quadrant and expressed in percentage using the formula:

\[
\text{Disease incidence} = \frac{\text{number of disease plants}}{\text{the total number of plants assessed}} \times 100
\]  

(1)

Faba bean gall severity was recorded on a scale of 0–9 (Ding et al., 1993), corresponding to free of disease (0: no visible infection on leaves) to highly susceptible (9: disease covering more than 80% of the foliar tissue, highly defoliation, and plants darkened and dead). Percent disease severity index (PSI) values were calculated from the severity scores using the following formula (Wheeler, 1969):

\[
\text{PSI} = \frac{\sum (\text{Disease grade} \times \text{number of plants in each grade})}{\text{Total number of plants x highest disease grade}} \times 100
\]  

(2)

To evaluate and rank the introduced improved varieties, the Rank-Based Quotient (RBQ) analysis was employed (Sabarathnam, 1988). The criteria used by farmers for their selection of the most preferred varieties were listed first during field evaluation. Farmers’ choice of a particular faba bean variety was influenced by several attributes like tillering capacity, resistance to pests and diseases, number of pods, grain and straw quality, resistance to waterlogging, and duration of the crop. Finally, they were asked to rank the varieties based on each specific ranking attributes according to their priority. The most preferred variety was ranked as 1 and the least preferred as 3. A higher mean rank indicates the most preferred variety and vice versa. A total of 16 farmers (5 females) were participated in this preference analysis. The RBQ was computed mathematically as follows:

\[
\text{RBQ} = \frac{\sum f_i (n + 1 - i)}{N \times n} \times 100
\]  

(3)

where

\[ f_i = \text{Frequency of farmers for the } i\text{th rank of the attribute,} \]
N = No. of farmers contacted for factor identification,

n = Maximum no. of ranks given for various factors,

i = Rank of the attributes.

Partial budgeting was employed to assess the profitability of any new technology to be imposed on the agricultural business (CIMMYT, 1988). The partial budget analysis allows assessing the impact of a change in the production system on a farmer’s net income without knowing all costs of production. Financial analysis was done using the prevailing market prices for inputs at planting and outputs when the crop was harvested. All costs and benefits were calculated on per hectare basis in Ethiopian birr (ETB ha⁻¹). Price of faba bean seed during planting was determined from the local market and it was 26 ETB kg⁻¹ for the local variety and 28 ETB kg⁻¹ for that of both Gora and Dosha varieties. The price of the fungicides Noble 25 WP was 700 ETB kg⁻¹ while the cost of labor used for spraying the fungicide was 400 ETB kg⁻¹. Mean values of the grain yield and straw yield were adjusted down by 10% to represent the yield under farm/farmer’s condition to avert certain unexpected yield losses. The average grain and straw market price after harvesting was found 23 and 2.75 ETB kg⁻¹ for all varieties. To measure the increase in net return associated with each additional unit of cost (marginal cost), the marginal rate of return (MRR) was calculated using the formula:

\[
MRR = \frac{\Delta NB}{\Delta TVC} \times 100
\]

where \(\Delta NB\) is change in net benefit compared with the unsprayed farmers practice and \(\Delta TVC\) is change in variable input cost compared with control.

3. Result and discussion

3.1. Yield and yield-related parameters

The result of agronomic traits and yield components, i.e. plant height, biomass and grain yield is summarized in Table 1. Analysis of variance showed that significant variation (\(P < 0.05\)) was observed among treatments in grain yield. The highest yield was obtained from a sprayed plot of Gora variety followed by Dosha variety while lower yield was scored from the unsprayed plot of the local variety. The improved faba bean technologies, Gora and Dosha, provided mean grain yields of 3.96 and 2.9 tons ha⁻¹, respectively. On the other hand, the local faba bean variety under farmers’ practice gave a mean grain yield of 1.5 ton ha⁻¹. The result thus revealed that Gora and Dosha improved faba bean technologies sprayed with Noble 25 WP fungicide have an overall yield advantage of 130.8% and 68.6%, respectively, over farmers’ unsprayed variety under the existing practice. Moreover, Table 1 shows that sprayed plots of Gora variety had a yield advantage of 70.3% when compared with farmers’ local variety sprayed with that of the same fungicide. Faba bean production and productivity in the highland area thus could be improved by adopting the recommended production practices including foliar application of fungicides on top of using improved varieties. The Tukey HSD test in Table 2, indicates that among treatments, Gora was the best performing technology in grain yield (\(P < 0.05\%). This finding seemed to resonate with the findings of Wondwosen et al. (2019a), who reported that the highest grain yield of 3.77 tons ha⁻¹ was gained from the variety Gora at the same location.

3.2. Disease parameters

The percentage severity index of faba bean gall was significantly reduced on sprayed plot than the unsprayed plots (Figure 1). The percent severity index of faba bean gall was reached zero on the sprayed plot of varieties Gora and Dosha at the final date of disease assessment. Whereas, the mean value of the unsprayed plot of local varieties was showed increasing PSI of faba bean gall from the initial to the final date of disease assessment. At the final date of disease assessment, the PSI of 64.2% for the unsprayed control plot was very high when compared to the sprayed plot of the same local variety (PSI = 20%).
### Table 1. Yield performance and disease score

| Varieties        | DI     | DS    | BY       | AGY     | YAd1 | YAd2 |
|------------------|--------|-------|----------|---------|------|------|
| Dosha            | 73.56  | 11.12 | 6398.83  | 2895.67 | 68.6 | 24.4 |
| Gora             | 56.13  | 8.83  | 8998.43  | 3962.67 | 130.8| 70.3 |
| Local sprayed    | 100    | 21.67 | 5511.42  | 2327.32 | 35.5 | -    |
| Local control    | 100    | 45.56 | 4624.02  | 1717.1  |      |      |
| Mean             | 82.42  | 21.79 | 6383.17  | 2725.69 |      |      |
| F-value          |        |       |          | 19.629  | 78.128| 5.430| 7.151 |
| Sig              | ***    | ***   | **       | **      |      |      |

** and *** significant at p < 0.01 and p < 0.05, respectively. DI = disease incidence, DS = disease severity, BY = biomass yield, AGY = average grain yield, YAd1 = yield advantage compared to the local unsprayed plots, YAd2 = yield advantage compared to the local sprayed plots.

### Table 2. Tukey-HSD post estimation of agronomic and farmer preference data

| Dependent Variable | Variety combination          | Mean Difference | Std. Error | Sig. |
|--------------------|------------------------------|-----------------|------------|------|
| Grain yield (kg)   | Control-local sprayed       | -610.22000      | 579.46180  | .725 |
|                    | Control-Dosha               | -1178.56667     | 579.46180  | .253 |
|                    | Control-Gora                | -2245.5667**    | 579.46180  | .020 |
|                    | Local sprayed-Dosha         | -568.34667      | 579.46180  | .764 |
|                    | Local sprayed-Gora          | -1635.34667*    | 579.46180  | .086 |
|                    | Dosha-Gora                  | -1067.00000     | 579.46180  | .323 |
| Biomass yield (kg) | Control-local sprayed       | -887.40616      | 998.47603  | .811 |
|                    | Control-Dosha               | -1774.81232     | 998.47603  | .349 |
|                    | Control-Gora                | -4374.40888**   | 998.47603  | .010 |
|                    | Local sprayed-Dosha         | -887.40616      | 998.47603  | .811 |
|                    | Local sprayed-Gora          | -3487.00272**   | 998.47603  | .033 |
|                    | Dosha-Gora                  | -2599.59656     | 998.47603  | .116 |
| Disease incidence (%) | Control-local sprayed     | 0.00000        | 6.86530    | 1.000 |
|                    | Control-Dosha               | 26.43667**      | 6.86530    | .020 |
|                    | Control-Gora                | 43.87000***     | 6.86530    | .001 |
|                    | Local sprayed-Dosha         | 26.43667**      | 6.86530    | .020 |
|                    | Local sprayed-Gora          | 43.87000***     | 6.86530    | .001 |
|                    | Dosha sprayed-Gora          | 17.43333        | 6.86530    | .127 |
| Disease severity (%) | Control-local sprayed     | 23.88889***     | 2.68793    | .000 |
|                    | Control-Dosha               | 34.43500***     | 2.68793    | .000 |
|                    | Control-Gora                | 36.72889***     | 2.68793    | .000 |
|                    | Local sprayed-Dosha         | 10.54611**      | 2.68793    | .018 |
|                    | Local sprayed-Gora          | 12.84000***     | 2.68793    | .006 |
|                    | Dosha sprayed-Gora          | 2.29389         | 2.68793    | .828 |
| Farmer preference (%) | Local-Dosha                 | -32.523333***   | 5.913910   | .000 |
|                    | Local-Gora                 | -34.321667***   | 5.913910   | .000 |
|                    | Dosha-Gora                 | -7.98333        | 5.913910   | .950 |

***, ** and * significant at p < 0.01, p < 0.05 and p < 0.1, respectively.
3.2.1. Disease incidence

Symptoms of the newly emerged disease, gall on faba bean, were evident on all plots at 35 to 40 days after planting. The incidence of the disease was assessed three times; starting before the first spray, during second spray, and 10 days after the last spray. The analysis of variance results indicated that the incidence of the disease showed a significant difference (p < 0.01) among treatments (Table 1). The maximum incidence of 100% was scored from both unsprayed control and sprayed plots of the local variety. In contrast, a combination of Gora variety with three-time foliar application of Noble 25 WP fungicide was effective in hindering the establishment and development of the disease. Hence, in turn, relatively a lower incidence (56.1%) was recorded from the variety Gora with Noble 25 WP, followed by Dosha variety sprayed with the same fungicide (73.6%). Three times foliar application of Noble 25 WP fungicide with Gora and Dosha varieties reduced disease incidence of faba bean gall by 43.9% and 26.4% compared to the unsprayed plots, respectively.

3.2.2. Percentage severity index

The results revealed that the highest final faba bean gall disease percent severity of 45.6% was recorded from the unsprayed control plots followed by the sprayed local variety with a percent severity of 21.7% (Table 1). On the other hand, the corresponding minimum final gall percent severities of 8.6% and 11.1% were recorded from Gora and Dosha varieties plots sprayed with Noble 25 WP fungicide, respectively. Percentage severity index showed a highly significant difference (p < 0.01) between the sprayed and unsprayed plots (Table 1). The use of Noble 25 WP foliar spray reduced percent severity index of faba bean gall by 52.4% compared to the unsprayed plots. This current finding coincides with the result of Abebe et al., 2018; Alemu & Tadele, 2017; Bitew & Tigabe, 2016; Hailemariam et al., 2017) that reported a foliar application of fungicides significantly reduced the severity of the disease compared to the unsprayed control plots. Figures 2 and 3 reveal the field performance difference between the existing farmers' practice and the improved management practices.

The integration of varieties with a fungicide spray, Noble 25 WP, has shown a highly significant difference (P < 0.01) on the percentage severity index (Table 2). Using a combination of Gora improved variety with foliar application of Noble 25 WP fungicides help to reduce the severity of the disease by 59.3% compared with that of the sprayed local variety and by 80.6% when compared with the local unsprayed plot. Similarly, Noble 25 WP foliar spray in combination with variety Dosha decreased PSI of faba bean gall by 48.7% and 75.6% over the sprayed and unsprayed plot of local variety in that order. On the other hand, there is no significant mean percent severity difference between the two improved varieties. A similar vein (Alemu & Tadele, 2017) reported that the integration of varieties with fungicide spray by Bayleton was showed a significant difference (P < 0.05) on the percentage severity index of faba bean gall. The use of Bayleton foliar spray reduced PSI of faba bean gall by 60.7%, 55.9% and
Figure 2. Performance of the unsprayed local variety.

Figure 3. Performance of the variety Gora sprayed with Noble 25 WP fungicide.
| Varieties | TC     | DR     | WL     | AD     | NPP    | SPP    | SSL    | EP     | LP     | EM     | EGY    | MP     | Average | Rank   | F-value |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|--------|---------|
| Dasha     | 91.66  | 70.83  | 89.58  | 79.17  | 68.75  | 87.5   | 75     | 70.83  | 72.92  | 70.83  | 77.08  | 88.89  | 78.59   | 2nd    |         |
| Gora      | 64.58  | 95.83  | 72.92  | 83.33  | 89.58  | 75     | 93.75  | 85.47  | 93.75  | 37.5   | 89.58  | 83.33  | 80.39   | 1st    | 21.339*** |
| Local     | 50     | 33.33  | 39.58  | 39.58  | 41.67  | 39.58  | 33.33  | 45.83  | 39.58  | 93.75  | 35.42  | 61.11  | 46.06   | 3rd    |         |

***significant at p < 0.01.

TC = Tillering capacity, DR = Disease resistance, WL = Resistance to waterlogging, AD = Adaptation to the area, NPP = No. of pods/plant, SPP = No. of seeds/pod, SSL = Seed size (largeness), EP = Early pod setting, LP = Late pod setting, EM = Early maturing, EGY = Expected grain yield, MP = Market preference.
46.7% on sprayed Adet Hana, Bulga70 and CS20DK varieties in their order over the unsprayed plot of these varieties.

3.3. Farmer preference

Participants farmers have identified 12 evaluation parameters in common to select their best faba bean technology. The comparison result of the RBQ value thus revealed that a technology that has higher aggregated value was preferred as a primary choice. According to Table 3, the average RBQ score value obtained from the ranks of the farmers showed that both the introduced improved varieties were preferred by the farmers while their local variety having low RBQ value. The Tukey HSD post estimation result showed that a highly significant mean difference was observed between the improved and local varieties (Table 2). However, there is no significant difference between Gora and Dosha varieties. Figure 4, highlighted the participation of FREG members during technology evaluation.

Table 4 shows that most of the respondents agreed that both the introduced improved varieties were well adapted to the area; had good tillering capacity; are moderately resistant to faba bean gall disease and water logging and are high yielder compared to their local varieties. The Mann–Whitney U test result revealed that except in disease resistance that showed a highly significant difference, in all cases there is no significant difference in farmers’ perception between these two improved cultivars. About 68.75% of the respondents were strongly agreed that the variety of Gora was found that relatively resistant to faba bean gall disease while it was 12.5% for Dosha improved variety. The result indicated that compared to the local variety the introduced improved cultivars were equally important for smallholder farmers in the study area. Moreover, Table 4 reveals that almost all the entire participant farmers were agreed on the effectiveness of the fungicide in minimizing the effect of the complexity of faba bean gall disease. The result indicated that about 75% of the respondents were strongly agreed on the effectiveness of the fungicide and more than 93% of them were decided to use the fungicide by next year.

3.4. Partial budget analysis

Results of the assessment of financial returns in this study indicated that using a combination of improved variety and fungicide application for faba bean gall management was profitable (Table 5). The highest net benefit of 82995.7ETB ha⁻¹ was obtained from the variety Gora sprayed three times with Noble 25 WP fungicide followed by Dosh variety combined with a three-time application of that same fungicide. On the other hand, the lowest net benefit (37538.6 ETB ha⁻¹) was obtained from the unsprayed control plot. Similarly, the highest (783.8%) marginal rate of return was obtained from the use of Gora variety with three times sprays of Noble 25 WP fungicide. This means that for every Birr 1.00 invested in Noble 25 WP fungicide and its application, farmers can expect to recover the Birr 1.00 and obtain an additional Birr 7.84. Further, the MRR result indicated that for every ETB 1.00 invested for
### Table 4. Summary of farmers’ perception about the improved technologies

| Perception attributes | Variety | Likert scale (%) | Mann-Whitney U Test |       |       |     |     |
|------------------------|---------|------------------|---------------------|------|------|-----|-----|
|                        |         |                  |                     | Mean Rank | Z    | Prob. > | |
|                        |         |                  |                     |            |     |       | \|z\| |
| The variety was well adapted to the area | Dasha  | 0   | 0   | 0   | 31.25 | 68.75 | 17.66 |
|                        | Gora    | 0   | 6.25 | 0   | 37.5  | 56.25 | 15.34 |
|                        |         |                  |                     |            |     |   0.824 | 0.4099 |
| The variety had good tillering capacity | Dasha  | 0   | 6.25 | 0   | 25    | 68.75 | 17.44 |
|                        | Gora    | 0   | 6.25 | 0   | 37.5  | 56.25 | 15.56 |
|                        |         |                  |                     |            |     |   0.664 | 0.5070 |
| The variety is resistant to FBG disease | Dasha  | 0   | 12.5 | 0   | 75    | 12.5  | 11.69 |
|                        | Gora    | 0   | 0    | 0   | 31.25 | 68.75 | 21.31 |
|                        |         |                  |                     |            |     |   -3.278 | 0.0010 |
| The variety is resistant to water logging | Dasha  | 0   | 0    | 0   | 87.5  | 62.5  | 16.03 |
|                        | Gora    | 0   | 0    | 0   | 93.75 | 62.5  | 16.97 |
|                        |         |                  |                     |            |     |   -0.599 | 0.5762 |
| The variety have relatively better yield | Dasha  | 0   | 0    | 0   | 43.75 | 56.25 | 16.00 |
|                        | Gora    | 0   | 0    | 0   | 37.5  | 62.5  | 17.00 |
|                        |         |                  |                     |            |     |   -0.354 | 0.7231 |
| Do you want to grow the variety next year? | Dasha  | 0   | 6.25 | 0   | 31.25 | 62.5  | 15.84 |
|                        | Gora    | 0   | 0    | 0   | 31.25 | 68.75 | 17.16 |
|                        |         |                  |                     |            |     |   -0.477 | 0.6332 |
| Noble fungicide is effective in minimizing the effect of FBG disease | 0   | 0    | 0   | 0    | 25    | 75    |       |
| Do you need to use the fungicide by next year? | 0   | 0    | 0   | 0    | 6.25  | 93.75 |       |
| Does the cost of the fungicide is affordable? | 0   | 0    | 0   | 0    | 12.5  | 87.5  |       |

Where, SDA = Strongly disagree, DA = Disagree, Un = Undecided, A = Agree, SA = Strongly agree.

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Noble 25 WP fungicide (three-time application using their local variety), farmers can expect to recover the ETB 1.00 and obtain an additional 2.99ETB.

### 3.5. Sensitivity analysis
The study needs away of estimating the range of prices under which a given treatment maybe recommended. A method for doing this is called sensitivity analysis. The best way to test a recommendation for its ability to withstand price changes is through sensitivity analysis (CIMMYT, 1988).

The average yields assumed in costs and return analysis are intended to simulate the average farm condition. However, crop yields vary from farm to farm, location to location, and across years. Crop prices also vary from year to year, location to location, and within a year, from month to month. Sensitivity analysis is a test of the enterprise to the variables or bad expectations. That is, assuming changes towards the worse in input and output prices or in some aspects of the enterprise that lead to a decrease in the volume of the production. Hence, a sensitivity analysis was done to determine the extent to which profitability of gall disease management options are affected by changes in input price and yield price. Holding the yield constant, a 25% yield price reduction, and a 25% input price increment from current estimated average yield price and input price levels, would result in a positive net benefit for gall disease management options (Table 6).

### 3.6. 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 other seven potential districts, unions, local NGOs, and administrative officials. Field day has a vital role in technology diffusion and adoption process to popularize the 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 females) participants visited the trial and applaud to Gora variety for its good growing performance. Also, participants during the field visit confirmed that Noble 25 WP is effective in controlling faba bean gall disease (Figure 5).

### Table 5. Partial budget analysis of different treatments

| Cost and benefit components | Control-unsprayed | Local-sprayed | Dosha-sprayed | Gora-sprayed |
|-----------------------------|-------------------|---------------|---------------|--------------|
| Adjusted grain yield (kg ha⁻¹) | 1545.39 | 2094.59 | 2606.1 | 3566.4 |
| Adjusted straw yield (kg ha⁻¹) | 2616.23 | 2815.13 | 3152.84 | 4352.18 |
| Gross field benefit (ETB ha⁻¹) | 42738.6 | 55917.18 | 67681.91 | 93995.7 |
| Seed cost (ETB ha⁻¹) | 5200 | 5200 | 7700 | 7700 |
| Fungicide cost (ETB ha⁻¹) | - | 2100 | 2100 | 2100 |
| Labor cost for spraying fungicide (ETB ha⁻¹) | - | 1200 | 1200 | 1200 |
| Total costs that vary (ETB ha⁻¹) | 5200 | 8500 | 11000 | 11000 |
| Net benefit/ETB | 37538.6 | 47417.18 | 56681.91 | 82995.7 |
| MRR (%) | - | 299.4 | 330.1 | 783.8 |

Seed cost for Gora & Dasha varieties = 26ETB/kg
For local variety = 26ETB/kg
Fungicide cost = 700ETB/kg
Labor cost for spraying fungicide = 400ETB/kg
Average grain selling price = 23ETB/kg
Average straw selling price = 2.75ETB/kg
Table 6. Sensitivity analysis of the treatments

| Item description                                      | Control-unsprayed | Local-sprayed | Dosha-sprayed | Gora-sprayed |
|-------------------------------------------------------|-------------------|---------------|---------------|--------------|
| Adjusted grain yield (kg ha⁻¹)                        | 1545.39           | 2094.59       | 2606.10       | 3566.40      |
| Adjusted straw yield (kg ha⁻¹)                        | 2616.23           | 2815.13       | 3152.84       | 4352.18      |
| Grain selling price (ETB kg⁻¹)                        | 23.00             | 23.00         | 23.00         | 23.00        |
| Straw benefit (ETB ha⁻¹)                              | 2.75              | 2.75          | 2.75          | 2.75         |
| Gross benefit (ETB ha⁻¹)                              | 42738.60          | 55917.18      | 67681.91      | 93995.70     |
| Seed cost (ETB ha⁻¹)                                  | 5200.00           | 5200.00       | 7700.00       | 7700.00      |
| Fungicide cost (ETB ha⁻¹)                             | -                 | 2100.00       | 2100.00       | 2100.00      |
| Total costs that vary (ETB ha⁻¹)                      | 5200.00           | 8500.00       | 11000.00      | 11000.00     |
| Net benefit/ETB                                       | 37538.60          | 47417.18      | 56681.91      | 82995.70     |

Sensitivity analysis

| + 10% cost of production (ETB ha⁻¹)                   | 5720.00           | 9350.00       | 12100.00      | 12100.00     |
| -10% grain selling price (ETB kg⁻¹)                  | 20.70             | 20.70         | 20.70         | 20.70        |
| -10% straw selling price (ETB kg⁻¹)                  | 2.48              | 2.48          | 2.48          | 2.48         |
| Gross benefit (ETB ha⁻¹)                              | 38464.74          | 50325.46      | 61749.55      | 84596.13     |
| Net benefit (Birr/ha)                                | 32744.74          | 40975.46      | 49649.55      | 72496.13     |
| + 15% cost of production (ETB ha⁻¹)                   | 5980.00           | 9775.00       | 12650.00      | 12650.00     |
| -15% grain selling price (ETB kg⁻¹)                  | 19.55             | 19.55         | 19.55         | 19.55        |
| -15% straw selling price (ETB kg⁻¹)                  | 2.34              | 2.34          | 2.34          | 2.34         |
| Gross benefit (Birr/ha)                               | 36327.81          | 47529.60      | 58319.02      | 79896.34     |
| Net benefit (Birr/ha)                                | 30347.81          | 37754.60      | 45669.02      | 67246.34     |
| + 20% cost of production (Birr/ha)                   | 6240.00           | 10200.00      | 13200.00      | 13200.00     |
| -20% grain selling price (ETB kg⁻¹)                  | 18.40             | 18.40         | 18.40         | 18.40        |
| -20% straw selling price (ETB kg⁻¹)                  | 2.20              | 2.20          | 2.20          | 2.20         |
| Gross benefit (Birr/ha)                               | 34190.88          | 44733.74      | 54888.49      | 75196.56     |
| Net benefit (Birr/ha)                                | 27950.88          | 36533.74      | 41688.49      | 61996.56     |
| + 25% cost of production (Birr/ha)                   | 6500.00           | 10625.00      | 13750.00      | 13750.00     |
| -25% grain selling price (ETB kg⁻¹)                  | 17.25             | 17.25         | 17.25         | 17.25        |
| -25% straw selling price (ETB kg⁻¹)                  | 2.06              | 2.06          | 2.06          | 2.06         |
| Gross benefit (Birr/ha)                               | 32053.95          | 41937.88      | 51457.96      | 70496.77     |
| Net benefit (Birr/ha)                                | 25553.95          | 31312.88      | 37707.96      | 56746.77     |

4. Conclusion and recommendations

The emerging faba bean gall disease, caused by Olpidium vicieae Kusano, is the major and most destructive disease in areas where faba bean is grown. The results revealed that the highest final faba bean gall disease percent severity of 45.6% was recorded from unsprayed control plots followed by sprayed local variety with percent severity of 21.7%. On the other hand, the corresponding minimum final gall percent severities of 8.6% and 11.1% were recorded from Gora and Dosha varieties plots sprayed with Noble 25 WP fungicide, respectively. Using a combination of Gora improved cultivar with foliar application of Noble 25 WP (Triadimefon) fungicides reduced the severity of the disease by 59.3% compared with that of the sprayed local variety and by 80.6% when compared with the local unsprayed plot. Also, the highest grain yield of 3.96 tons ha⁻¹ was obtained from a sprayed plot of Gora variety. The result thus revealed that Gora improved faba bean technologies sprayed with Noble 25 WP fungicide had an overall yield advantage of 130.8% over farmers’ unsprayed variety under the existing practice. Most
of the respondents agreed that both the introduced improved varieties were well adapted to the area; had good tillering capacity; are moderately resistant to faba bean gall disease and water logging and are high yielders compared to their local variety. Moreover, almost the entire participant farmers were strongly agreed on the effectiveness of the fungicide and more than 93% of them were decided to use the fungicide by next year. Similarly based on the partial budget analysis result, the highest (740.3%) marginal rate of return was obtained from the use of Gora variety with three times sprays of Noble 25 WP. Further, the sensitivity analysis result showed that this treatment (Gora variety with Noble 25 WP fungicide) is acceptable to a 25% price increment for Noble fungicide and 25% price decrement of faba bean grain and straw yield. In the end, the results of this study suggested that the proper application of fungicides combined with improved varieties is important for the economic management of the disease.

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