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Yield Gap Analysis of Common Bean through On-Farm Demonstrations in Central Rift Valley (CRV) of Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study proposes to analyze the yield gap of common bean varieties through on-farm demonstrations in the central Rift Valley of Ethiopia. The districts were purposefully selected based on their common bean production potential. A total of sixteen (16) trial farmers were selected from potential haricot bean-growing kebeles. Two improved common bean varieties, SAB-632 and SAB-736, and one standard check (Nasir) were planted on a plot size of 0.125ha. The result shows the highest mean yield was 26 qt/ha for SAB-632 in Shalla, followed by (24.4 qt/ha) at Adami Tulu Jido Kombolcha district. The increase in productivity of SAB-632 at Adami Tulu Jido Kombolcha and Adama district over respective standard checks was 20.35 % and 51.5 % respectively. The mean extension gap was 5.7 qt/ha in SAB-632, while -1.07 qt/ha was in SAB-736 variety. In addition the mean technology index was 7.7 % in the SAB-736, while it was 32 % for SAB-736 varieties. Across all locations, SAB-632 varieties have a technology index of less than 15 % indicating that their performance by these varieties in those district conditions was more than satisfactory. There is a need to adopt and scale up SAB-632 on a larger scale to enhance the adoption of variety.

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Keywords: Demonstrations; extension gap; technological gap; technology index; common bean.

1.INTRODUCTION

"The common bean (*Phaseolus vulgaris* L.) is the most important food legume in Ethiopia. The crop is cultivated in several agro-ecological zones and farming systems and mainly grown by small-scale farmers for household consumption, marketing and soil fertility improvement purposes" [1]. "Ethiopian farmers have a higher preference to grow common beans, compared to other legumes, because they mature early, which helps them obtain cash income to buy food and other household needs. It also serves as an emergency crop in times of crop failure" [2]. In Ethiopia a range of bean types are grown, but small white and red beans are the most common and preferred types.

"The small white beans are mainly grown in the Oromiya (in the Central Rift Valley) and Amhara regions, for the export market. Ethiopia exports common beans to the canning industry in Europe" [3]. "In addition to this the country exported 40 percent of its total common bean production in 2010" [4]. "The small red beans, on the other hand, are grown mainly in the southern parts of the country, and they are used for local and regional markets and for household consumption" (Rubyogo et al., 2011), [1]. "Recently, due to the rising demand in the international and domestic markets, the common bean has been grown in almost all parts of the country, with varying intensity" [1]. Common bean production in the Central Rift Valley (Oromiya region) comprises about 50% of the total bean production of the country.

"In Ethiopia, the National Common Bean Research Program which is based at the Melkassa Research Center (MARC), plays an important role in meeting the increasing demand for the crop by releasing improved common bean varieties. Starting in the 1970s, the National Bean Program has developed and released more than 55 common bean varieties. Even though strong efforts have been made to disseminate these varieties, using different extension channels, the adoption rate has been slow, mainly due to the inaccessibility of improved seed" [5]. Over the past fifteen years, the national bean research program, in collaboration with the International Center for Tropical Agriculture (CIAT), has been working on the decentralization of seed systems. Consequently, a dramatic increase in the area of production and productivity of the common bean has been observed in the country.

"Consequently, because of this area under common bean production in Ethiopia in 2007/2008 was 231,443.06 hectares and has reached 306,186.59 hectares in 2017/2018 with production of 2,414,17.6.4 and 5,209,79.3 tons, respectively" [6]. "The national average yield of common beans is low ranging from 16 qt/h, which is far below the corresponding yield recorded at research sites 28.9 qt/ha" [7]. "Although considerable efforts have been made to improve the productivity of the crop in the country, there is still a huge gap between the potential and actual yield" (Rubyogo et al., 2011). "Among the 55 improved varieties, only 18% were disseminated and adopted" [3]. To improve technology dissemination and adoption, and to better address the food requirements of smallholder farmers, addressing the productivity gap is necessary. For the sustainable production of common beans, a number of technologies are available, but farmers' perceptions towards the adoption of good agricultural practices are very poor and they are still practicing unscientific methodologies.

Many production technologies for common bean cultivation have been evolved to increase the productivity, but farmers have hardly adopted a few of them and those in a non-scientific manner. To sustain the production of common bean, several steps are still required. In this regard, to sustain the potential production and consumption system of common bean, the Melkassa Agricultural Research Center (MARC), agricultural extension and communication research process had demonstrations of recently realized common bean varieties in the 2019 cropping season. The basic aim of the demonstration is to promote and extend improved common bean technologies along with capacity building for farmers. In view of this, the aim of frontline demonstrations is to identify the extension gap, technology gap and technology index in common bean production through various extension methods and technologies. The study implemented on-farm demonstration on common bean varieties with the main objective of boosting the production and productivity of pulses through front line demonstrations with the latest and specific transfer of technologies at demonstrations hosting farmers' fields.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The central rift valley (CRV) is located between longitudes 38° 12'–39° 60' E and latitudes 6° 58'–8° 47' N, predominantly characterized by arid and sub-humid climates with mean maximum and minimum temperatures of 28.5°C, and 12.6°C respectively. The area is also characterized by a bi-modal rainfall pattern ranging between 175 and 358 mm of rainfall during March to April and 420– 680 mm during June to September, the main season [8]. The predominant farming system is a mixed rain-fed production system consisting of grain crops and livestock. The study sites of Adama, Adami Tulu Jido Kombolcha (ATJK), and Shalla districts are located in the Oromia National Regional State in the Central Rift Valley (CRV) in Ethiopia.

"A brief description of the demonstration host districts goes as follows: Adama district is bordered in the south by the Arsi zone, in the southwest by Bora district, in the west by Lume district, in the north by the Amhara National Regional State, and in the east by Boset district. It is located 100 km southeast of the capital city of the country, Addis Ababa (Finfine). The topography is characterized by plain, undulating land, gentle slopes, and rugged terrain. Its mean annual temperature and rainfall vary between 15°C and 20°C and 700–800 mm, respectively. Geographically, it is located between 8° 33' 35" to 8° 38′ 46" latitudes and 390 10′ 57 to 390 30' 15" longitudes" [9].

"Adami Tulu Jido Kombolcha (ATJK) district is one of the districts of the East Showa Zone of Oromia Regional State, bordered by Dugda district to the north and Arsi Negelle district from the south while Zuway Dugda is district from the east and SNNP regional state is from the west. It is found 168 km south of Addis Ababa with a total area of 140,324.6 km2. The area receives a mean annual rainfall of 690 mm and it has an altitude between 1500 and 2300 meters above sea level" [10,11]. "The major economic sectors of the district are crop production, animal husbandry, and fishing. The main crops produced are maze, common bean, teff and wheat" [12].

"Shalla district is one of the districts of the West Arsi Zone of Oromia Regional State, bordered by Siraro district to the south, on the west by the SNNP Region, on the north by Shalla Lake, and on the east by Shashamane. Its western boundary is defined by the course of the Bilate River. It is found 279 km south of Addis Ababa, with a total area of 140,324.6 km2.The area receives annual rainfall ranging from 1000 to 1200 mm and the main growing season (rainy season) is from June to September. The altitude of the district is estimated to be in the range of 1000 and 2300 meters above sea level. The mean annual temperature of the district lies between 22°C and 25°C. Agriculture is the primary economic activity and about 95% of the population is engaged. The major crops produced in the district are maize, wheat, common bean and teff" [13]. The location of the study sites is shown in Fig. 1.

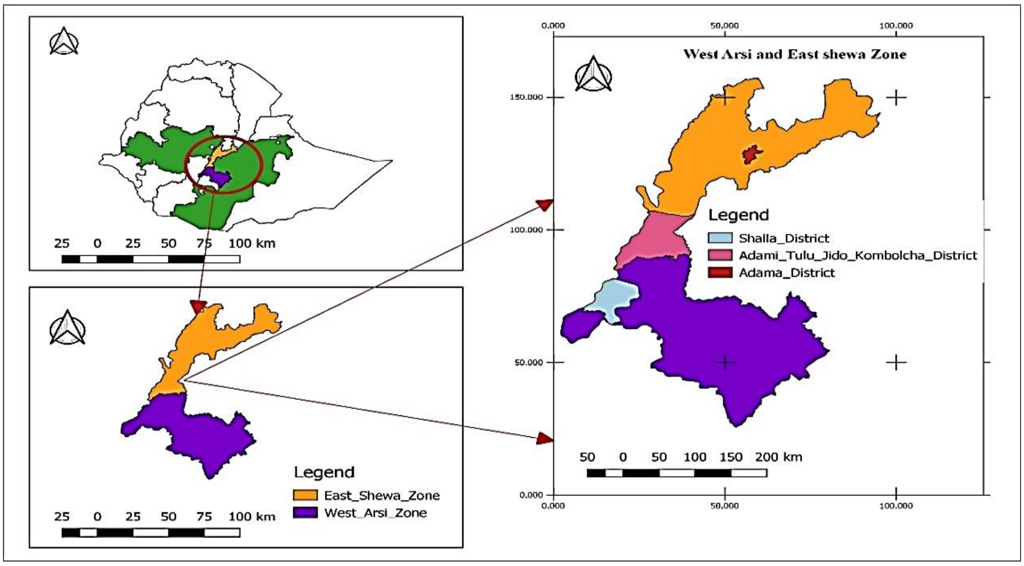

Fig. 1. Map of the study area
Source: GIS shape file of Ethiopian administrate map

2.2 Site and Demonstration Hosting Farmers Selection

The present demonstration was conducted in the central rift valley of Ethiopia, Adama Adami Tulu Jido Kombolcha (A/T/J/K) and Shalla districts. Two kebeles from each district and a total of four kebeles were addressed. The demonstration was conducted on each kebele in the 2019 cropping year. The districts were selected purposefully depending on the potential of common bean production and crop adaptation areas. Target demonstration kebeles were further selected purposefully depending on their common bean production potential and accessibility for researchers' monitoring, evaluation. The farmers' selection was based on their landholding and ownership of farmers, willingness of the farmers to conduct experiment properly under the regular follow up of the researchers, and their capability to transfer knowledge and create awareness about the varieties among their neighbors and surrounding non-host farmers. Accordingly, sixteen demonstrations hosting farmers on common bean were conducted at farmers fields in selected districts to assess its performance during the Meher cropping season.

2.3 Research Design and Agronomic Managements

The materials for the present study, comprised high yielding improved common bean quality seed varieties were SAB-632 and SAB-736. Nasir commercially and locally cultivated varieties were used as a standard check. Every demonstration consisted of both improved and local varieties with 0.125 ha of area each and total of 16 demonstrations in a 4 ha area were conducted. In every demonstration plot, a full package of recommended practices was adopted whereas, in the adjoining farmers' fields, crop was grown as per the practices followed by the farmers, which served as a control or standard check. Before the conduct of the demonstration farmers was specific skill training was imparted to the selected hosting farmers, who follow the package and management practices of common bean production.

Accordingly, after the conduct of training, critical inputs like seed, fertilizer, fungicides, and insecticides, were facilitated to the beneficiaries by Melkassa agricultural researchers during the course of training and visits. All agronomic practices were fully implemented. The study sites were plowed three times with oxen before planting common beans. After the soil is prepared for sowing, planting is undertaken. Planting time depends on the onset of rainfall. Usually, when rainfall starts in mid-June, planting during late June and mid-July is recommended. It is recommended common beans to be sown in rows should be with a seed rate of 100 kg/ha. The spacing between rows should be 40 cm, and seeds in the row 10 cm apart. In poor soil, adding 100 kg/ha of DAP during planting is recommended.

When the plants are deficient in nitrogen, they show leaf yellowing. At this moment, 50-100 kg of urea could be applied as a top dressing before flowering emphasized, and a comparison has been made with the existing practices. Thinning was done 15 days after emergence. Two rounds of hand weeding were undertaken during the growing period of the demonstrations experiments. Accordingly, farmers underwent the first hand weeding two weeks after planting, and the next weeding five weeks after sowing. Farmers field day, regular field visits of farmers, and extension workers were organized at demonstration plots to disseminate the message on a large scale to provide opportunities for other farmers. Finally, the harvested product from the central rows was sun-dried, threshed and measurements were made for grain yield and seed weight.

2.4 Data Collection and Analysis

The objective of the yield gap analysis was to study the gaps between the potential yield and demonstration yield, extension gaps, and the technology index. In the present study, data on the demonstration yield of the common bean crop were collected from data collected from 16 farmers demonstration plots. Besides the data on local practices commonly adopted by the farmers of these districts were also collected. The data was further analyzed by using simple statistical tools. The technology gap, extension gap and technological index were calculated by [14] as given below.

Potential yield is the maximum possible yield obtained when the crop is grown using research recommended management practices [15]. For this study, the crop potential yield data was taken from the Crop Variety Registry Book [16].

Technology gap

It means the difference between the potential yield and the yield of the demonstration plot.

$$Technology\ gap = Potential\ yield - Demonstration\ yield \ldots \quad (1)$$

The Extension gap

It means the differences between demonstration plot yield and farmer yield.

$$Extension\ Gap = Demonstration\ yield - Farmers\ yield \ldots \quad (2)$$

Technology Index

It indicates the feasibility of the evolved technology in farmers' fields. The lower the value of the technology index, the higher is the feasibility of the improved technology.

$$\text{Technology (\%)} = \frac{Potential\ yield - Demonstration\ yield}{Potential\ yield} \quad (3)$$

3. RESULTS AND DISCUSSION

Frontline demonstrations are effective educational tools for introducing various new technologies to the farmers to boost their confidence level by comparing of productivity levels between good agricultural practices in demonstration trials. The performance of the common bean crop owing to the adoption of improved technologies is assessed over a period of the 2019 cropping year. This parts shows and discusses the performances of improved common bean varieties across locations.

3.1 Common Bean Varieties Yield Performance Across Locations

A comparison of productivity levels between the improved varieties and the standard control (Nasir) is shown in Figure 2. Accordingly, the result obtained from the newly released improved common bean varieties as well as the standard control is described. Accordingly, the highest mean yield recorded for SAB-632 (Tafach) and SAB-736 (Ado) common bean varieties is 26 qt/ha and 20 qt/ha respectively, and both are recorded at shalla district over the standard check. The result agree with Abebe T et al. [17] in common bean who reported improved varieties had significantly higher yield than that of the standard check (Batu). The mean yield for SAB-632 (Tafach) is 25 qt/ha, 22 qt/ha and 26 qt/ha at A/T/J/K, Adama, and Shalla district respectively. Similarly, the mean yield obtained for SAB-736 (Ado) common bean varieties is 18.4 qt/ha, 13 qt/ha and 20 qt/ha at A/T/J/K, Adama, and Shalla districts respectively.

The mean yield of standard check (Nasir) were 20.3 qt/ha,14.4 qt/ha and 19.4 qt/ha at A/T/J/K, Adama, and Shalla districts, respectively. Comparing the mean yield obtained at three locations, the mean yield obtained at A/T/J/K district for both SAB-632 (Tafach) and SAB-736 (Ado) improved common bean varieties, including the standard check (Nasir) is better than that of the remaining two locations. The lower mean yield is recorded at A/T/J/K, and Adama for SAB-736 (Ado) varieties due to extreme environmental stresses. The maximum mean grain yield across varieties was recorded at Shalla district from the variety SAB-632 (Tafach) (26 qt/ha), while the minimum yield was recorded at Adama from the variety SAB-736 (Ado) (13 qt/ha).

The mean yield performance of the varieties at A/T/J/K (24.4qt/ha) and Adama (22 qt/ha) was relatively high. The mean yield of standard check (Nasir) varieties at A/T/J/K (20.3 qt/ha) followed by Adama (14.4 qt/ha) was relatively high as compared to the improved SAB-736 (Ado) varieties. So, the three locations, A/T/J/K, Adama and Shalla are found to be more suitable environments for SAB-632 (Tafach) common bean production compared to SAB-736 (Ado) and standard check (Nasir). In A/T/J/K and Adama location standard check (Nasir) varieties produced a higher grain yield than the improved SAB-736 (Ado) varieties.

The transfer of improved farm technology under frontline demonstrations resulted in a significantly higher grain yield of common bean under demonstration plots over the standards check yield rather than A/T/J/K and Adama district on SAB-736 (Ado) varieties, which may be attributed to the adoption of recommended agro technologies in demonstration during the study period.

3.1.1 Yield increments and advantages

During the period of study, it was observed that in SAB-632 (Tafach) improved common bean varieties on demonstration of advanced technologies increased the productivity of all three locations over the respective local checks (Nasir) (Table 1). In case of SAB-736 (Ado) improved common bean varieties recorded lower productivity at A/T/J/K and Adama districts 9.04

qt/ha, 11.7 qt/ha as compared to standard checks (Nasir) 20.25 qt/ha, 14.36 qt/ha, respectively. The increase in productivity of SAB-632 (Tafach) at A/T/J/K and Adama district over respective standard checks was 20.35 % and 51.5 %. The finding is compatible with Fitsum et al. [18] who reported that he grain yield obtained in the new varieties, including the deployment of improved production practices, was higher than those obtained with the farmers' practice.

The higher productivity of SAB-632 (Tafach) at A/T/J/K and Adama districts was due to the sowing of latest high yielding varieties and adoption of improved management practices. The resulting match with Dembele E and Ashenafi D [19] who reported that the improved common bean varieties had a significant yield advantage over the standard check (Hawassa Dume). Similarly, the percentage increase in the standard check (Nasir) yield over SAB-736 (Ado) was 9.04, and 11.7 at A/T/J/K and Adama districts respectively. This result shows the improved SAB-736 (Ado) common bean varieties had a lower yield as compared to the standard check (Nasir) (Table 1).

3.1.2 Extension yield gap

The extension gap is defined as the difference between demonstration yield and the yield of farmers practices. As the result indicates in Table 2 below the highest extension gap was reported in the A/T/J/K district (3.2 qt/ha) of SAB-632 (Tafach) common bean varieties, followed by Adama (7.39 qt/ha) and Shalla (6.4 q/ha) districts. The finding is consistent with Takele et al. [20]. Relatively, a lower extension gap was showed for SAB-736 (Ado) common bean varieties in Adama (1.7 qt/ha) and A/T/J/K (-1.83 qt/ha) districts respectively. Further the result in argument are also reported by Kumar et al. [21].

To reduce the extension gap, we need to educate farmers to implement the improved production technologies of improved common bean varieties. Much effort needs to be made by the Bureau of Agriculture, research centers, NGOs, farmers cooperatives, government institutes, and University, and through various extension programs to disseminate the improved common bean practices. More extension gaps indicate the high acceptance of advanced technologies (Table 2).

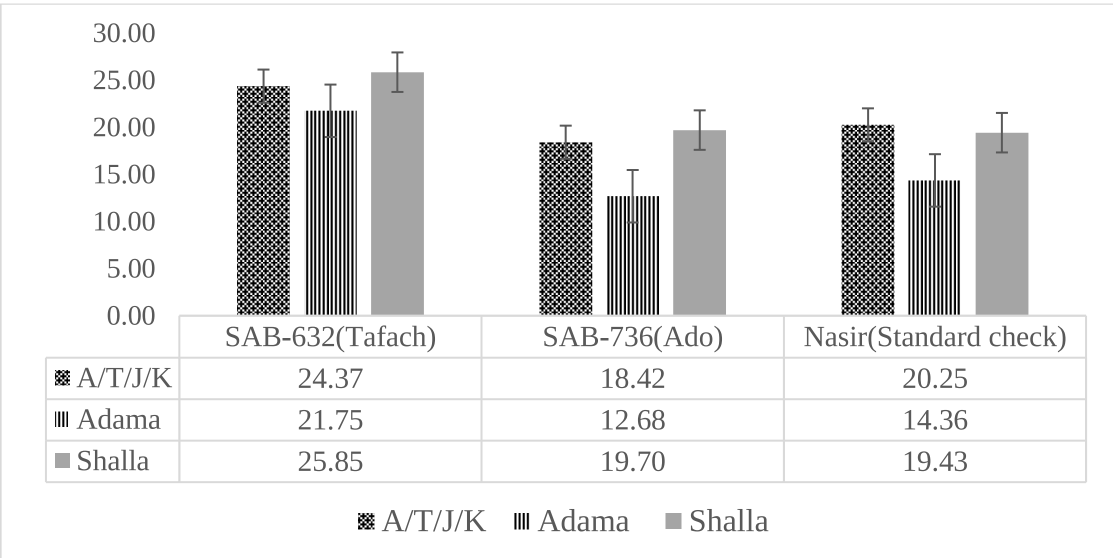

Fig. 2. Demonstration yield performance of common bean varieties, 2019 (N=16)

Table 1. On-farm demonstration field yield advantage and yield increases of CB varieties

Locations	Varieties mean yield in (qt/ha)			YD increase(qt/ha)		YD advantages (%)	
	SAB-632	SAB-736	Check	SAB-632	SAB-736	SAB-632	SAB-736
A/T/J/K(N=5)	23.37	18.42	20.25	4.12	-1.83	20.35	-9.04
Adama(N=5)	21.75	12.68	14.36	7.39	-1.73	51.5	-11.7
Shalla(N=6)	25.85	19.70	19.43	6.42	0.27	33	1.4
Combined Mean	23.99	16.93	18	5.98	-3.29	35	-19.34

Source: on-farm demonstration field,2019

Table 2. Mean yield of improved CB varieties, extension gaps, and technology gap (qt/ha)

Locations	Varieties	#Hosting farmers	Potential yield	Yield of check	Demonstration yield	Technology gap	Extension gap	Technology index (%)
A/T/J/K	SAB-632	5	26	20.25	23.4	2.6	3.2	10
	SAB-736		25		18.42	6.5	-1.83	262
Adama	SAB-632	5	26	14.36	21.75	4.3	7.39	16.3
	SAB-736		25		12.68	12.3	-1.7	49.3
Shalla	SAB-632	6	26	19.43	25.85	0.15	6.4	0.6
	SAB-736		25		19.70	5.3	0.3	21.2
Mean/Total	SAB-632	16	26	18	24	2	5.7	7.7
	SAB-736		25		17	8	-1.07	32

Source: on-farm demonstration field,2019

3.1.3 Technology yield gap

The technology gap is the result of differences between potential yield and demonstration yield. As the study result indicated, an overall mean technological gap was observed at 2 qt/ ha and 8 qt/ha for SAB-632 and SAB-736 common bean varieties over locations. The technology gap may be attributed to the dissimilarity in the soil fertility status and weather conditions, and similar findings were found by Kumar et al. [21]. Less technology gap revealed better adaptability of common bean crop variety in a particular area; among all demonstration plots in shalla (0.15 qt/ha), A/T/J/K (2.6 qt/ha) and Adama (4.32 qt/ha) districts, a yield gap was observed for SAB-632 (Tafach) varieties respectively [22].

The technological gap during the study period varied to the extent of 0.15 to 4.3 qt/ha for SAB-632 (Tafach), while 5.3 qt/ha to 12.3 qt/ha for SAB-736 (Ado) common bean varieties over locations. The overall average technological gap was 2qt/ha for SAB-632 (Tafach) and 8qt/ha for SAB-736 (Ado). The technology gap was highest (12.3qt/ha) in Adama district for SAB-756 (Ado) and lowest (0.15 qt/ha) in Shalla for SAB-632 (Tafach) common bean varieties. The technology gap observed may be attributed to dissimilarity in the soil fertility status, agriculture practices and local climatic situation (Table 2).

3.1.4 Technology index

The technology index showed the feasibility of the evolved technology in the farmers' fields. The lower the value of the technology index, the greater the is feasibility of technology. Accordingly, the result shown in table 2 below shows that the lowest value (0.6%) of the technology index was observed in the Shalla district, followed by A/T/J/K (10%) for SAB-632 (Tafach) common bean varieties. Variation in technology index (ranging between 0.6-262%) and overall average technology index was observed at 7.7 percent for SAB-632 (Tafach) and 32% for SAB-736 (Ado) varieties during the cropping year, which may be attributed to the dissimilarity in soil fertility status, low or untimely rainfall, insect-pests, and diseases infestations. Comparatively in Adama, and Shalla districts, low indexes were observed and reflect high feasibility on farmers' fields for the SAB-632 (Tafach) and SAB-736 (Ado) varieties respectively.

The highest value of the technology index was reported at A/T/J/K district under SAB-736 (Ado) (262 %) followed by 49.3% at adama district. This results are also in conformity with the findings of Effa W et al. [23] on teff crop where found the improved Dursi teff varieties had the higher technology index than the standard check (Guduru). Except at A/T/J/K and Shalla district, the SAB-736 (Ado) common bean varieties and the other SAB-632 (Tafach) varieties have a technology index of less than 15 percent indicating that the performance of these varieties in those district conditions was more than satisfactory and these varieties adopt a in lower rainfall distribution.

4. CONCLUSION AND RECOMMENDATION

Three varieties of common bean were demonstrated (two newly released (*SAB-632 (Tafach) and SAB-736 (Ado))* and one standard check (Nasir)) planted with their full packages at 16 farmers field each on a plot size of 0.125 ha replicating farmers' fields. In an effort of bridge the knowledge and skill gaps of smallholder farmers was changed through intensive training especially on the importance of newly introduced haricot bean production and field day were organized and farmers evaluated the demonstration plots. Based on the yield data, the highest mean yield recorded for SAB-632

(Tafach) and SAB-736 (Ado) common bean varieties is 26 qt/ha and 20qt/ha, respectively, and both are recorded at Shalla districts. The lower mean yield is recorded at A/T/J/K and, Adama for SAB-736 (Ado) varieties. Similarly, the mean yield of standard check (Nasir) varieties at A/T/J/K (20.3 qt/ha) followed by Adama (14.4 qt/ha) was relatively high as compared to the improved SAB-736 (Ado) varieties. So, the three location, A/T/J/K, Adama, and Shalla, are found to be more suitable environments for SAB-632 (Tafach) common bean production compared to SAB-736 (Ado) and standard check (Nasir). There exists a wide gap in potential yields, demonstration yields and farmers' plot yields due to technological and extension gaps. The highest extension gap was reported in the A/T/J/K district (3.2 qt/ha) of SAB-632 (Tafach) common bean varieties, followed by Adama (7.39 qt/ha) and Shalla (6.4 qt/ha) districts. The technology gap was highest (12.3 qt/ha) in Adama district for SAB-756 (Ado) and lowest (0.15 qt/ha) in Shalla for SAB-632 (Tafach) common bean varieties. In Adama, and shalla districts, low indexes were observed and reflect high feasibility on farmers' fields for the SAB-632 (Tafach) and SAB-736 (Ado) varieties respectively. The study emphasizes the demonstration of location specific crop management practices, improved technologies embedded with high yielding varieties to minimize these gaps. From the present study, it can be concluded that the use of improved SAB-632 (Tafach) varieties in cultivation can reduce the technology gap to a substantial extent has been found to be more productive and yields might be averagely increased up to 35 percent in the area. Moreover, the districts bureau of agriculture extension department strictly focuses on disseminating the proven SAB-632 (Tafach) variety in common bean production systems through large scale demonstrations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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