Yield gap analysis of common bean through on-farm demonstrations in Central Rift Valley(CRV) of Ethiopia

Abstract

This study proposed to analysis yield gap of common bean varieties through on-farm demonstrations in central Rift Valley of Ethiopia. The districts were purposively 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 each 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 %. 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 SAB-736,while 32 % for SAB-736 varieties. Across all location SAB-632 varieties have given technology index of less than 15 % indicating that the performance by these varieties in those district conditions was more than the satisfactory level. There is a need to adopt and scale up SAB-632 on a larger scale to enhance the adoption of variety.

Keywords: *Demonstrations, extension gap,technological gap, technology index, and 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 (CSA, 2015). Ethiopian farmers have a higher preference to grow common beans, compared to other legumes, because they mature early, which helps them to obtain a cash income to buy food and other household needs. It also serves as an emergency crop in times of crop failure (Legesse et al., 2006). In Ethiopia a range of bean types are grown in the, 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 (Ferris and Kaganzi, 2008). In addition to this the country exports 40 percent of its total common bean production in 2010 (FAOSTAT, 2015).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; CSA, 2015). Recently, due to the rising demand in the international and domestic market, the common bean is being grown in almost all parts of the country, with varying intensity (CSA, 2015). 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 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 (Buruchara et al., 2011). Over the past fifteen years, the national bean research program, in collaboration with the International Center for TropicalAgriculture (CIAT) has been working on the decentralization of the 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 5,209,79.3tons, respectively (CSA, 2018). The National average yield of common beans is low ranging from 16qt/h, which is far below the corresponding yield recorded at research sites 28.9Qt/ha (Amanuel, 2018). 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 (Ferris and Kaganzi, 2008). To improve technology dissemination and adoption, To better address the food requirements of smallholder farmers, addressing the productivity gap is necessary. For the sustainable production of common bean, numbers of technologies are available but farmers' perception towards adoption of good agricultural practices is very poor and they are still practicing the unscientific methodologies.

Many production technologies for common bean cultivation have been evolved for increasing the productivity but farmers has hardly adopted a few of them and those in a non-scientific manner. To sustain 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 the demonstrations of recently realized common bean varieties in 2019 cropping season. The basic aim of the demonstration is to promote and extend improved common bean technologies along with capacity building of farmers. In view, the aim of frontline demonstrations is to identify 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 main objective to boost the production and productivity of pulses through front line demonstrations with latest and specific transfer of technologies at demonstrations hosting farmers' fields.

2.Materials and method

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 climate with mean maximum and minimum temperatures of 28.5°C and 12.6°C respectively. The area also characterized by a bi-modal rainfall pattern ranging between 175 and 358 mm rainfall during March to April and 420– 680 mm during June to September, main season (Gizachew and Andualem, 2014). The predominant farming system is mixed rain-fed production system consisting of grain crops and livestock. The study sites 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 bordering in the South with Arsi zone, in the Southwest with Bora district, in the West with Lume district, in the North with the Amhara National Regional State, and in the East with 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 slope, and rugged terrains. 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 (Hurgesa et al., 2019).

Adami Tulu Jido Kombolcha(ATJK) district is one of the districts of East Showa Zone of Oromia Regional State, bordered by Dugda district to North and Arsi Negelle district from South while Zuway Dugda district from East and SNNP regional state is from West. It is found at 168 km South of Addis Ababa with total area of140,324.6 km2. The area receives mean annual rainfall of 690 mm and it has an altitude between 1500and 2300 meters above sea level (Bezabeh et al., 2010; EEPCo, 2013). The major economic sectors of the district are crop production, animal husbandry, and fishery. The main crops produced are a maze, common bean, teff and wheat (Jemila, 2014).

Shalla district is one of the districts of West Arsi Zone of Oromia Regional State, bordered by Siraro district to 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 total area of 140,324.6 km2.The area receives annual rainfall ranging from1000 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 between 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 engaged. The major crops produced in the district are maize, wheat, common bean and teff (Ahmed, 2018).location of the study sites is shown figure 1 below.

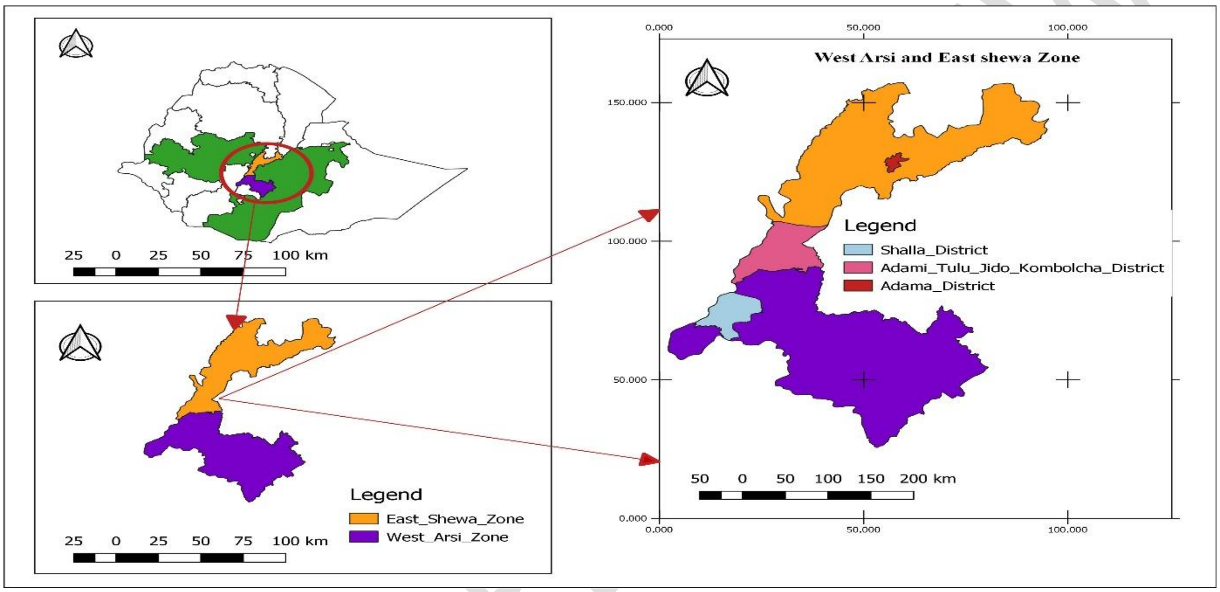

Figure 1.Map of the study area

Source: GIS shape file of Ethiopian administrate map

2.2.Site and demonstration hosting farmers selection

The present demonstration was conducted in 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 2019 cropping year. The districts were selected purposively depending on the potential of common bean production and crop adaptation area. Target demonstration kebeles further selected purposively depending on their common bean production potential and accessibility for researchers' monitoring, evaluation. The farmers' selection was based on 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 farmersfield in selected districts to assess its performance during Meher cropping season seasons.

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 used. Nasir commercially and locally cultivated varieties were used as standard check.Every demonstration consisted of both improved and local variety having 0.125 ha area each and totally 16 demonstrations in 4 ha area was conducted. In every demonstration plot, 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 control/ standard check. Before the conduct of the demonstration farmers were specific skill training were imparted to the selected hosting farmers follow the package and management practices of common bean production.

Accordingly after the conduct of training critical inputs like seed, fertilizer, fungicide and insecticide were facilitated to the beneficiaries by melkassa agricultural researchers during the course of training and visitsmade. All agronomic practice were fully implemented. The study sites were plowed three time by using oxen before planting common bean. After the soil is prepared for sowing planting were 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 bean to be sown in rows 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 urea could be applied as top dressing before flowering emphasized and comparison has been made with the existing practices. Thinning was done 15 days after emergence. Two rounds of hand weeding were undertaken the growing period of the demonstrations experiments. Accordingly, farmers were undertaken the first hand weeding two weeks after planting, and the next weeding five weeks after sowing.Farmers field day, regular field visit of farmers and the extension workers was organized at demonstration plots to disseminate the message at 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 one hundred 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 the data on demonstrations yield of 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 this 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 (Samui *et al.*, 2000)as given below.

Potential yield is the maximum possible yield obtained when the crop is grown applying research recommended management practices (FAO, 2015). For this study, the crop potential yield data was taken from the crop Variety Registry Book (MoANR, 2016).

Technology gap

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

$$Technology\ gap = Potential\ yield - Demonstration\ yield \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

The Extension gap

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

$$Extension\ Gap = Demonstration\ yield - Farmers\ yield \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Technology Index

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

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

3.Results and Discussion

Frontline demonstrations are effective educational tools in introducing various new technologies to the farmers to boost the farmerconfidence level by comparison of productivity levels between good agricultural practices in demonstration trials. The performance of common bean crop owing to the adoption of improved technologies is assessed over a period of 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 presented infigure 2. Accordingly, the result obtained from the newly released improved common bean varieties as well as the standard control is described.Accordingly, highest mean yield recorded for SAB-632(Tafach) and SAB-736 (Ado) common bean varieties is 26qt/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*. (2022) in common bean who reported improved varieties had significantly higher yield than that of the standard check(please write with characters TNR, 12).The mean yield for SAB-632(Tafach) is 25 qt/ha, 22qt/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 18.4qt/ha, 13qt/ha and 20qt/ha at A/T/J/K, Adama and shalla district respectively.

The mean yield of standard check_(Nasir) were 20.3qt/ha,14.4qt/ha and 19.4qt/ha at A/T/J/K, Adama and shalla district 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 (22qt/ha) was relatively high. The mean yield of standard check(Nasir) varieties at A/T/J/K (20.3qt/ha) followed by Adama (14.4qt/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 more suitable environment 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 high grain yield over the improved SAB-736 (Ado) varieties.

The transfer of improved farm technology under frontline demonstrations resulted in significantly higher grain yield of common bean under demonstration plots over thestandards 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 agrotechnologies in demonstration during study period.

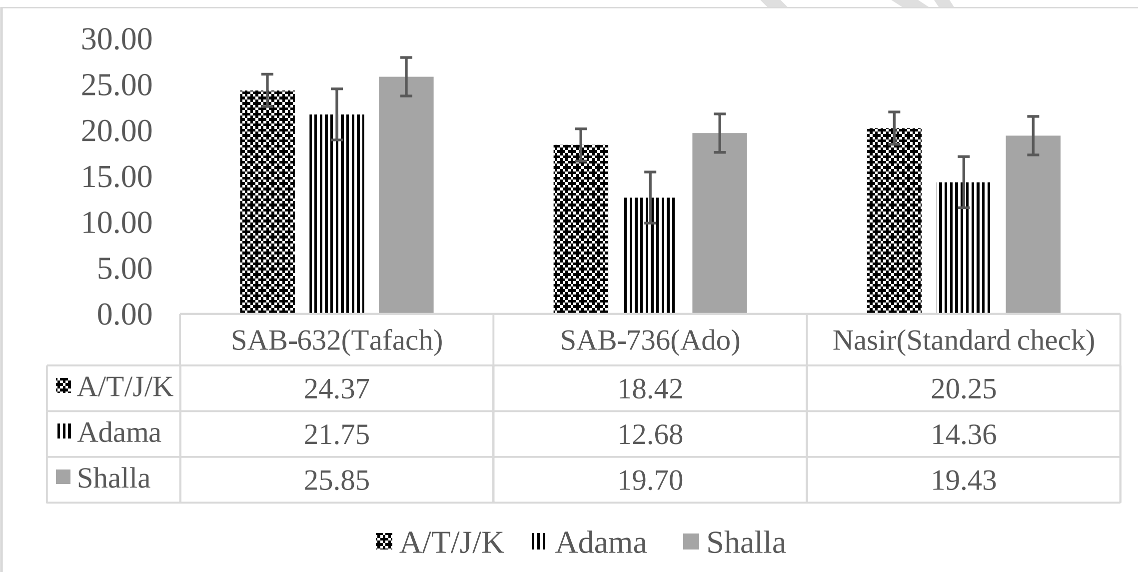

Figure 2. Demonstration yield performance of Common bean varieties, 2019 (N=16)

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 productivity of all the three locations over respective local checks(Nasir) (Table 1). In case of SAB-736(Ado) improved common bean varieties recorded lower productivity of at A/T/J/K and Adama districts 9.04qt/ha, 11.7qt/ha as compared to standard checks(Nasir) 20.25qt/ha, 14.36qt/ha, respectively.The increase in productivity of SAB-632 (Tafach) at A/T/J/K and Adama district over respective standard checks were 20.35 % and 51.5 %.The finding is compatible with Fitsumet al. (2022) who reported thathe 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 district were due to the sowing of latest high yielding varieties and adoption of improved management practices.The resulting match with Dembele E. and Ashenafi D, (2018) who reported that the improved common bean varieties had a significant yield advantage over the standard check(please write with characters TNR, 12).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 district respectively. This result shows the improved SAB-736 (Ado) common bean varieties had lower yield as compared to the standard check (Nasir)(Table 1).

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

3.1.2.Extensionyield gap

The extension gap is defined as the difference between demonstration yield and the yield of farmers practice. As the result indicates in the tables 2 below the highest extension gap was reported in the A/T/J/Kdistrict (3.2qt/ha) of SAB-632 (Tafach) common bean varieties, followed by Adama (7.39 qt/ha) and shalla (6.4 q/ha) district. The finding is consistent with Takele et al,.(2011). Relatively, a lower extension gap was showed for SAB-736(Ado) common bean varieties in Adama (1.7qt/ha)and A/T/J/K(-1.83qt/ha) districts respectively. Further the result in argument are also reported by Kumar et al. (2021).

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 bureau of agriculture, research centers, NGOs, farmers cooperatives, Government institutes and University's and through various extension programs to disseminate the improved common bean practices. Because more extension gaps indicate the high acceptance of advanced technologies (Table 2).

3.1.3.Technologyyield gap

The technology gap is the output of differences between potential yield and demonstration yield. From the study result indicated, overall mean technological gap was observed as 2 qt/ ha and 8qt/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. (2021). Less technology gap revealed better adaptability of common bean crop variety in a particular area; among all demonstrations plots in shalla (0.15qt/ha), A/T/J/K(2.6qt/ha) and Adama (4.32qt/ha) districts, a yield gap was observed for SAB-632 (Tafach) varieties respectively.

The technological gap during the study period varied to the extent of 0.15 to 4.3 qt/ha for SAB-632(Tafach), while 5.3qt/ha to 12.3qt/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 (0.15qt/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 at the farmers' fields. The lower the value of technology index, the more is feasibility of technology. Accordingly the result shows in the table 2 below 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 7.7 percent for SAB-632 (Tafach) and 32% for SAB-736(Ado) varieties during the cropping year, may be attributed to the dissimilarity in soil fertility status, low or untimely rainfall, insect-pests, and diseases infestations. Comparatively in Adama, and shalla district, 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(please write with characters TNR, 12)et al.,(2022) on maize crop.Except at A/T/J/K and Shalla district SAB-736(Ado) common bean varieties the other SAB-632 (Tafach) varieties have given technology index of less than 15% percents indicating that the performance by these varieties in those district conditions was more than the satisfactory level and these varieties adopts in lower rainfall distribution.

Table2.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/T	SAB-632		26	18	24	2	5.7	7.7
otal	SAB-736	16	25		17	8	-1.07	32

Source: on-farm demonstration field,2019

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 its full packages at 16 farmers field each on a plot size of 0.125 ha replicating farmersfield. In an effort of bridging 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 evaluate the demonstration plots. Based on the yield data highest mean yield recorded for SAB-632(Tafach) and SAB-736 (Ado) common bean varieties is 26qt/ha and 20 qt/ha respectively; and both are recorded at shalla district. 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 more suitable environment for SAB-632(Tafach) common bean production compared to SAB-736 (Ado) and standard check (Nasir). There exists a wide gap in the 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 (3.2qt/ha) of SAB-632 (Tafach) common bean varieties, followed by Adama (7.39 qt/ha) and shalla (6.4 q/ha) district. The technology gap was highest (12.3qt/ha) in Adama district for SAB-756(Ado) and lowest (0.15qt/ha) in shalla for SAB-632(Tafach) common bean varieties. In Adama, and shalla district, 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 use of improved SAB-632(Tafach) varieties cultivation can reduced the technology gap to a substantial extent has been found more productive and yield might be average increased up to 35 per cent in the area. Moreover, the districts Bureau of agriculture extension department strictly focus on disseminating the proven SAB-632(Tafach) variety in common bean production systems through large scale demonstrations.

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