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Demonstration and Promotion of Recently Released Improved Mid Altitude Sub humid Agro Ecology Maize (*Zea mays* L.) Varieties in Benishangul Gumuz Region at Pawe District, Western Ethiopia

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Abstract **– Maize (*Zea mays* L.) is the leading productive among cereals and stable crop in Benishangul Gumuz Regional State where highly produced at Metekel, Assosa and Kamashi zones with Maokomo special District. Maize technology advancement was directed to the pastoralist and agro pastoralist areas of settlers and natives in Metekel zone. The demonstration fields were conducted at Pawe District specifically in Mender-4 and Mender-10 kebeles in the 2020 main cropping season using single plot area of 0.25ha for each variety at each location with active involvement of farmers. Field days were established at each demonstration site to investigate farmers' trait and variety preference using pair wise and direct matrices selection method. From the field days direct and pair wise matrices result revealed that grain yield, disease tolerance, striga weed tolerance and lodging tolerance were selected as the indispensable traits for maize production by farmers and based on the field performance BH549 was selected as first variety in Meneder-4 kebele while BH546 was first in Mender-10 kebele and better in striga weed tolerance, but the highest overall mean grain yield result after harvest was recorded from BH549 (7.4 t ha-1) followed by BH546 (7.0 t ha-1) whereas from the standard check (BH540) was obtained the least (5.6 t ha-1). Therefore as a result of this productive idea of expression over farmer's standard check variety in Pawe District, it is recommended to be introduced first BH549 followed by BH546 maize varieties in the production system of further scaling up and breeders should consider these important traits selected by farmers for further advancement through breeding.**

Keywords **– Matrices, Pair Wise, Ranking, Traits and Grain Yield.**

I. Introduction

Agriculture is a backbone and has a pronounced role in the livelihood of African countries which provides the main source of food, income and employment (Alston and Pardey, 2014). It is also the central pillar of developing and subsidizing about 50% of the GDP and 85% of the total service economy of Ethiopia [4]. Crop production has the primary share in agriculture. Maize (*Zea mays* L.) is the third most vital cereal crops after wheat and rice in the world economy and the second most food consumption next to wheat globally [14]. It is as well the most important among cereals providing food and income in Sub-Saharan African (SSA) countries including Ethiopia [1]. In Ethiopia maize has also the contribution more than 75% of its national production area coverage supplied the calorie intake [10]. The CSA [6] report revealed that from the total grain crop area coverage, 81.46% was covered by cereals of which maize accounted 21.7% and 32.5% while tef recorded 24.1 % and 17.2% for both area coverage and grain production respectively in Ethiopia. In Benishangul Gumuz Regional State maize is also the most productive and stable cereal crop across the region. In this region, maize is highly produced at Assosa, Metekel and Kamashi zones with Maokomo special District where it is the first most significant crop together with the production area revelation and its productivity per unit area. In Metekel zone there is favorable cyclic rain fall distribution and cultivable land convenience at different Districts which is suited for major crops production including maize sorghum and finger millet, but maize is the most dominant crop among cereal crops providing 4.3 t ha-1 average grain yield and greater than the national average yield (4.24 t ha-1) of the country. It is mainly exploited as stable crop used for injera making and preparing local alcoholic drinks "tella" and "areki". It is also utilized as income source providing the market access with its straw for animal feed. In Pawe District maize is also very common and the leading crop has a long history produced and exploited for various aspects in the diet and home alcoholic drinks such as 'tella' provides high social heritages in 'Ekub', 'Edir' and 'Serg' program in the society.

However, its production and productivity highly constrained via biotic and abiotic factors in the mid and lowland sub humid agro ecologies of Ethiopia including Benishangul Regional State. Biotic stresses embrace gray leaf spot, turcicum leaf blight, common leaf rust, phaeosphaeria leaf spot and maize streak virus [2]; [19] while poor soil fertility with low P and N, including climate change [7]; [13]; [16] are abiotic stresses. Undesirable environmental variations are estimated a total for Africa over 95 % of the farmers on rain-fed agriculture [18] like Ethiopia. Crop production path ways are also the actual causes of environmental change in agricultural practices disturb in Ethiopia exposed to disaster outstanding to increase stresses like human population, land degradation and food insecurity. In the situation of extremes, "killing degree days" above 29°C for maize are commonly modeled to decrease yields due to direct tissue or enzyme damage [5]. Soil degradation is another serious concern in agricultural ecologies despoiled soil organic carbon problematic in crop production for Ethiopia [20]. Settlers in Pawe District mainly at Mneder-4 and Mender-10 kebeles similarly constrained by those factors mainly, lack of improved hybrid maize varieties and certified seed access in addition poor farmers' awareness about improved maize technologies are critical draw bags. Pawe Agricultural Research Center has a long history of establishment with the settlers which provides impact full research technologies delivering and promoting with various research disciplines in the country and near the established areas. Maize research program is one of the crop research components in the center doing together with Bako National Maize Research Coordinating Center responsible with the adaptation and promotion of improved maize technologies which are pertinent for the mid and low land sub humid agro ecologies. Therefore the objective of this work was demonstrating and promoting improved maize varieties at Pawe District on farmers' field and enhancing the adoption of improved technologies.

II. Materials Methods

2.1. *Site Descriptions*

The demonstration was conducted in Metekel zone at Pawe District (Mender-4 and Mender-10 kebeles) located about 573km far from Addis Ababa in the North West direction of Ethiopia and situated with an altitude of about 1000 - 1120 m.a.s.l. The area receives about 1500mm mean annual rainfall with 16°C-34.6°C minimum and maximum average annual temperature. Mixed agriculture is used with the dominant Nitosol type in both sites of the demonstration fields through the variation in its vegetation coverage enables Pawe District to have various cropping system. The demonstration was done in the 2020 main cropping season with active participation of farmer's and the collaboration of District Bureau of Agriculture using BH546 and BH549 varieties as the demonstrated plots while BH540 as standard check. These varieties were planted at each location of individual farmer's field using 0.25ha plot area of each variety with spacing of 30cm between two consecutive plants and 75cm between two successive rows which is equivalent to planting density of approximately 44,444 plants ha-1. Synthetic fertilizer NPS and urea were applied (120 and 150) kg ha-1 respectively with 25kg ha-1 seed rate. NPS fertilizer was applied at planting while urea was applied after thinning. Each maize variety was planted two seeds per hill and latter thinned to one seedling per station to maintain the recommended planting density per unit area. All agronomic practices were attended by the farmers themselves with the assistance of the researchers, Kebele developmental agents and District experts with the agronomic recommendations at both sites.

2.2. *Data Collection*

From the demonstration fields the grain yield and some yield related parameters were collected.

- The data were collected from 10m by 10m sample plot areas of each demonstration site.
- Number of ears harvested per plot, Ear weight (kg plot-1) and moisture content (%) at harvest were recorded.
- Finally the harvested field weight per plot in kg ha-1 was converted into t ha-1 for each variety by the method of Galinat in CIMMYT (1988).

$$\frac{\text{Grain yield}\left(\frac{\text{ton}}{\text{ha}}\right) = \text{Field weight}\left(\frac{\text{kig}}{\text{plot}}\right) \text{X} (100 - \text{MC}) \text{ X } 0.8 \text{ X } 10000}{1000\,(100 - 15) \text{ X } 100}$$

Where: MC = grain moisture content at harvest in %, 0.8 = shelling co-efficient, 100 = harvested plot area in m2), 1 hectare = 10,000m2, 1ton= 1000kg and 85% = Standard Value of Grain Moisture at 15%.

2.3. *Field Days*

Farmers' field days were prepared at the physiological maturity stage of the crop at both locations including male and female farmers' participation. From Mender-4 demonstration site, male participants were 41 while females were 7 with the total of 48 participants. Similarly in Mender-10 demonstration field males were 64 while females were 8 with the total of 72 contestants also participated. During the field days the variety evaluation and selection technique was done through group discussion. Variety selection technique was conducted using the matrix of direct and pair wise ranking methods stated by Harder [11] and Gay [9]). The rating performance was scored from 5 to 1 (5 = excellent, 4 = very good, 3 = good, 2 = poor and 1 = very poor) for each variety and important traits. The relative weight was also, calculated based on the frequency of selection scores for each variety and trait through the matrix during the active participation of farmers, then ranked. Finally the trait of expected grain yield was cross checked with the actual grain yield after harvest. Pair wise comparisons was done using the following steps: First farmers' selection criteria were identified through group discussion and arranged (Table 1) to be ranked in a square matrix, then pairs of criteria were compared across rows, finally the results of each evaluated criteria were ranked and assigned relative weights. This procedure was applied at both locations. Finally the best variety was selected by the farmers and recommended for further scaling up.

2.4. *Data Summary*

The quantitative data were summarized using the actual grain yield based on the formula stated by Galinat in CIMMYT [8] while qualitative data were done using the frequency distribution of matrix ranking using a tool for decision-making and prioritization procedure stated by Harder [11] and Gay [9] The rate distribution and relative weight during pair wise ranking and direct matrix values were summarized *via* the following two steps:

Step 1. The numeric values of frequencies were sum up that an option was elected as favored over another prospect and place the number of times in the score column for the corresponding row, so:

a. First count the number of frequencies each trait voted throughout the matrix, then sum up each trait value to detect the score

b. Place the score values of each trait at the right side of the column

c. Put the rank values which provide comparing the score of each trait acquired in another column next to the score column.

d. If the trait and /or variety didn't acquire any score during the field days, put zero at the ranking column.

Step 2. The relative weights were assigned calculating considering the total of all the weights could be 100% and followed the qualitative scoring and ranking given in the first step. The one very simple method to get that initial set of values is to assume a linear proportion between all the weights and solve using the formula: $a_1x + a_2x + a_3x ... + a_nx = 100\%,\ x = \frac{100}{a_n}$ Where: a_1, a_2, $a_3 \ldots a_n$, indicated the number of frequencies each trait voted throughout the matrix and x indicates the percentage (%) value of relative weight for each trait multiplied by a_1, a_2, $a_3 \ldots a_n$.

Table1. Summarized farmers' Selection Criteria for the Variety Evaluation during the field days at both locations in 2020.

Field days and Selection Time	**Selection Criteria**
At the physiological maturity period of the crop	Expected grain yield
	Maturity date
	Stalk and root logging tolerance
	Ear aspect
	Striga weed tolerance
	Bare tipness and husk cover
	Disease tolerance
	Plant and ear height

III. Results and Discussion

Farmers were actively participated and observed the performance of each variety during the field days. Based on their preference at Mender-4 location, disease tolerance was selected as the first very essential trait while expected grain yield, striga weed tolerance and bare tipness were also selected as the second important traits (Table 2). Hence the relative weight of disease tolerance was 18.9% while expected grain yield, striga weed tolerance and bare tipness were accounted 16.2% for each (Table 3). Similarly at Mender-10 kebele farmers were also put their trait preference as striga weed tolerance was selected since the primary incredibly vital trait while bare tipness and disease tolerance were selected the second important traits (Table 5). So, the relative weight of striga weed tolerance was accounted 20% while bare tipness and disease tolerance were 17.2% for each (Table 6). The farmers' trait preferences scientifically confirmed that traits like grain weight, ear aspect, bare tipness, husk cover and disease tolerance are important for maize production [17]. The other reports also revealed that the striga weed (Striga hermontica) (Mbwaga and Massawe, 2001), and root lodging are the major factors influencing maize grain yield potential [12]. Most traits were observed very promising and voted as excellent (5) and very good (4) for BH549 and BH546, but the overall rank showed that BH549 was selected first with the actual grain yield (7.9 t ha-1) followed by BH546 with its grain yield 7.3 t ha-1 at M-4 kebele (Table 4 and 8). Similarly at Mender-10 kebele most traits were also observed as promising for both varieties rated excellent and very good and the overall rank indicated BH546 selected first followed by BH549. Conversely after harvested the highest actual grain yield (6.8 t ha-1) was recorded from BH549 followed by BH546 (6.7 t ha-1) in (Table 7 and 9). In general both BH549 and BH546 varieties were promising and preferred by farmers for the commercial production inter impulsively; the only pain in the neck is certified seed access through the farmers while BH540 variety didn't elected by farmers at both locations. Most traits were also observed and scored poor and very poor at this variety except maturity date and it become out of the production.

Table 2. Pair wise ranking of farmers' and experts' maize trait preference criteria at M-4 Kebele in 2020.

Selection Criteria		GY	MD	S & RLT	EA	SWT	BTP	DT	P & EH	Total Score	Rank
		1	2	3	4	5	6	7	8		
1.	GY		1 (29)	1 (5) 3(27)	1 (23)	1(5) 5(26)	1(4) 6(35)	7 (36)	1 (36)	6	2nd
2.	MD			3 (36)	4 (35)	5 (38)	6(38)	7 (38)	8 (13) 2 (16)	2	5th
3.	S & RLT				3(38)	5(33)	6(33)	7 (34)	2 (16) 8 (18)	3	4th
4.	EA					5 (31)	6(32)	7 (33)	4 (28) 8 (3)	2	5th
5.	SWT						6(34)	5 (20) 7(11)	5 (32)	6	2nd
6.	BTP							7 (29)	6(35) 8 (1)	6	2nd
7.	DT								7 (38) 8 (1)	7	1st
8.	P&EH									5	3rd

Note: GY = Grain yield, MD = Maturity date, S & RLT = Stalk and root lodging tolerance, EA = Ear aspect, SWT = Striaga weed tolerant, BTP = Bare tip problem, DT = Disease tolerance, P&EH = Plant and ear height. The above table (Table 2), the numbers inside the bracket indicated the number of participants provided vote for each trait while the numbers outside the bracket represented selected trait.

Table 3. Direct matrix ranking evaluation of varieties by group of farmers and experts at M-4 Kebele in 2020.

No.	Selection Criteria	Relative Weight	BH-546	BH-549	BH-540
1.	Grain yield (GY)	16.2%	4(8)	5(31)	4(5)
2.	Maturity date (MD)	5.4%	5(21)	5(37)	5(21)
3.	Lodging tolerant (S & RLT)	8.1 %	5(20)	4(37)	2(22)
4.	Ear aspect (EA)	5.4%	4(20)	5(35)	3(22)
5.	Striga weed tolerant (SWT)	16.2 %	5(1)	2(1)	3(1)
6.	Bare tip (BTP)	16.2%	5(27)	5(46)	2(27)
7.	Disease tolerance (DT)	18.9%	3(33)	4(26)	2(26)
8.	Plant and ear height (P&EH)	13.5%	4(33)	4(26)	3(26)

Note: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1 = very poor. From table 3 the number inside the bracket also showed the number of participants provided vote for each trait while the numbers outside the bracket represented the trait value (excellent very poor).

Table 4. Pair wise ranking and selection result of maize varieties at Pawe District (M-4) in 2020.

Varieties		BH-546	BH-549	BH-540	Total score	Rank
		1	2	3		
1.	BH-546		1(16) 2(31)	1(45)	2	2nd
2.	BH-549			2(45)	2	1st
3.	BH-540				0	0

Note: In table 4, the numbers inside the bracket indicated the number of participants provided vote for each variety while the numbers outside the bracket represented selected variety.

- 2x+2x+0x =100, 4x =100, x = 25.
- BH546 = 2x = 50% and BH549 = 2x = 50%, but BH5469 has got better election than BH546 by 15 votes.
- The subsequent active participation of both participants favored and ranked as:
- BH-549 = 1st
- BH-546 = 2nd

BH-546 Maize field BH-549 Maize field BH-540 Maize field

Fig. 1. Maize Demonstration Field at Pawe (M-4 Kebele) in 2020.

Group-A Group-B

Fig. 2. Direct matrix ranking evaluation of varieties by group of farmers and experts at M-4 Kebele in 2020.

Table 5. Pair wise ranking of farmers' and experts' maize trait preference criteria at maturity stage at M-10 Kebele in 2020.

Selection Criteria		GY	MD	S & RLT	EA	SWT	BTP	DT	P & EH	Total Score	Rank
		1	2	3	4	5	6	7	8		
1.	GY		1(61)	3(50)	1 (19) 4(41)	5(57)	6(59)	1 (11) 7(51)	1(62)	4	4th
2.	MD			3 (13) 2(53)	4 (21) 2(33)	5(65)	6(66)	7 (66)	8 (47)	2	5th
3.	S & RLT				3(69)	5(71)	6(66)	3 (12) 7(56)	3(70)	5	3rd
4.	EA					5 (71)	6(69)	4(7) 7(57)	4(70)	4	4th
5.	SWT						5(71)	5(64)	5(72)	7	1st
6.	BTP							6(9) 7(57)	6(71)	6	2nd
7.	DT								7(71)	6	2nd
8.	P&EH									1	6th

Note: GY = Grain yield, MD = Maturity date, S & RLT = Stalk and root lodging tolerant, EA = Ear aspect, SWT = Striaga weed tolerance, BTP = Bare tip problem, DT = Disease tolerance, P&EH = Plant and ear height. From table 5, the numbers inside the bracket revealed the number of participants provided vote for each trait while the numbers outside the bracket represented selected trait.

Table 6. Direct matrix ranking evaluation of varieties by group of farmers and experts at M-10 Kebele in 2020.

Selection Criteria		Relative Weight	BH-546	BH-549	BH-540
1.	Expected grain yield	11.4%	5(38) 4(7)	5(30)	1(58)
2.	Maturity Date	5.7%	5(47)	4(15)	4(10)
3.	Stalk & Root lodging Tolerant	14.3%	5(56)	3(27)	4(50)
4.	Ear aspect	11.4%	4(10)	5(47)	1(57)
5.	Striga weed tolerant	20.0%	5(59)	4(2)	1(28)
6.	Bare tip	17.2%	5(39)	5(54)	1(59)
7.	Disease tolerant/ resistance	17.2%	4(12)	4(6)	1(2)
8.	Plant and ear height	2.86%	5(47)	4(12)	1(58)

Note: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1= very poor. In table 6, the numbers inside the bracket also indicated the number of participants provided vote for each trait while the numbers outside the bracket as well represented the trait value (excellent very poor).

Table 7. Pair wise Ranking of Maize Varieties at Pawe District in 2020 main season both farmers' and experts' M-10 Kebele.

Varieties		BH-546	BH-549	BH-540	Total score	Rank
		1	2	3		
1.	BH-546		1(38) 2(23)	1(58)	2	1st
2.	BH-549			2(68)	2	2nd
3.	BH-540				0	0

Note: From the table (Table 7), numbers inside the bracket showed the number of participants granted vote for each variety while the numbers outside the bracket represented the variety.

- 2x + 2x + 0 = 100, 4x = 100, x = 25
- BH546 = 2x = 50% and BH549=2x= 50%, but
- BH546 has got a total of 96 votes while BH549 has got 91 votes, hence:
- BH546 = 1st
- BH549 = 2nd

BH-540 BH-546 BH-549

Fig. 4. Maize Demonstration Field day at M-10 Kebele in 2020.

Table 8. Demonstrated varieties and their actual grain yield at M-4 Kebele in 2020.

No.	Varieties	Harvested Area (m^2)	No of Plants at Harvest	No of Harvested Ears	No of Rotted Ears	Field Weight (kg)	Moisture Content (%)	Grain yield (t ha^{-1})
1.	BH546	100	323	378	1	97.8	20.4	7.3
2.	BH549	100	365	417	20	106.7	21.5	7.9
3.	BH540	100	301	343	37	72.2	20.3	5.4

Table 9. Demonstrated varieties and their actual grain yield at M-10 Kebele in 2020.

No.	Varieties	Harvested Area (m^2)	No of Plants at Harvest	No of Harvested Ears	No of Rotted Ears	Field Weight (kg)	Moisture Content (%)	Grain yield (t ha^{-1})
1.	BH546	100	370	523	32	94.6	24.8	6.7
2.	BH549	100	365	423	24	89.8	20.1	6.8
3.	BH540	100	343	384	84	84.7	24.8	5.9

IV. Conclusions and Recommendations

The credit of advanced maize technologies require prevalent progression for latest varieties in new areas where the varieties are not pronounced. In both locations the two improved maize varieties were accepted *via* farmers through direct and pair wise ranking technique. BH-549 maize variety was selected first followed by BH-546 at M-4 kebele while at M-10- kebele BH549 was liable by *striga hermontica* weed than BH546 variety whereas superior than the standard check variety BH540. Generally the average grain yield BH549 was the first followed by BH546 at both locations and more advanced than BH540. Therefore it is highly recommended that for further popularization and commercialization BH549 maize variety is advisable to be used under optimum soil condition followed by BH546 while under striga prone areas comparatively BH546 is better than BH549 and it is recommended to be used as striaga tolerant and also has narrow leaf structure makes it preferable for inter cropping with legume crops. It is also extremely suggested to breeders enhanced farmers' trait preference including striga weed, disease and lodging tolerance associated with bare tipness in addition to grain yield for further variety advancement through breeding.

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