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Full Length Research Paper

Performance of climber common bean (*Phaseolus vulgaris* L.) lines under Researcher Designed Farmer Managed (RDFM) system in three bean agro-ecological zones of Malawi

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An on-farm study was carried out in 2003-2004 and 2004-2005 growing seasons under rain-fed condition in five sites namely Thondwe and Matapwata in Zomba and Thyolo districts respectively, Chipuka in Ntchisi district, Ntchenachena and Ngong'a in Rumphi district representing three bean agro-ecological zones of Malawi. Seven climber common bean entries; CAB 19, RWV 1046, BCMV B4, AND 659, RWV 1042-2-3, 5P/5 and DC 86-244 were evaluated for their performance and stability across sites and two seasons under Researcher Designed Farmer Managed (RDFM) system. Entries DC 86-244, AND 659 and BCMV B4 were early maturing in most sites of the trial. DC 86 244 and AND 659 were also high yielding and had larger seed sizes compared to other entries. RWV 1046 and RVW 1042-2-3 were also high yielding though had smaller seed sizes. Stability analysis identified entries CAB 19 and DC 86 244 as stable entries across sites and seasons. Among environments, Ng'onga, Chipuka and Thondwe were high yielding. Ntchenachena was more stable but lower yielding compared to other sites. Matapwata was highly unreliable as heavy rains followed by dry spells characterised the site which resulted in loss of all bean entries in 2004-2005 growing season.

Key words: Agro-ecological zones, AMMI, on-farm, *Phaseolus vulgaris* L., Researcher Designed Farmer Managed (RDFM), seed size, stability.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the most preferred leguminous crops grown by small holder farmers in Malawi. Its consumption in Eastern and Southern Africa exceeds 50 kilograms per person per year (Mauyo et al., 2007). The crop is cheaper to grow and requires less land area as it can be intercropped with other food crops (Mwang'ombe et al., 2008). Common bean has a high percentage of protein as compared to maize, rice and cassava. This protein is high in lysine, which is relatively deficient in maize, rice and cassava, the staple carbohydrate food crops in Malawi. When beans are consumed with these carbohydrate staples, the mixture provides a balanced diet (CIAT, 2004). Beans are a cheaper source of proteins that is especially important in the diet of resource poor people living far from the lakeshore areas where fish is the main source of protein (Mekbib, 2002; CIAT, 2004; Osorio-Diaz et al., 2003; Parra et al., 2004). The legume has been used as a substitute for other sources of plant and animal protein in the industrial preparation of the commonly consumed food such as ice cream or regionally consumed food such as miso in Japan and kishk in Eastern Europe (Nestares et al., 2001). Additionally, dry legume grain is relatively easy to store at the small scale farm level as compared to beef,

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Table 1. Description of locality and elevation of the trial sites.

Trial site	Locality	Elevation (masl)
Ntchenachena	10^0 40' S 34^0 5' E	4100
Ng'onga	10^0 55' S 33^0 57' E	3500
Chipuka	13^0 30' S 34^0 5' E	1800
Thondwe	15^0 29' S 35^0 14' E	2500
Matapwata	15^0 57' S 35^0 10' E	3600

poultry or fish (Mkandawire et al., 1995). Apart from food, the crop is also an important source of income due to the increasing demands both domestic and export markets (Mauyo et al., 2007).

Despite all these benefits, the crop is faced with a lot of production challenges at a small holder farmers' level in Malawi. The challenges include insect pests, diseases and low yield per unit area. This results in the reduction of supply for the crop to meet the country's demands. Insect pests damaging common beans throughout Malawi include bean beetles, aphids (*Aphis fabae* and *Aphis craccivora*), bean fly (*Ophiomyia spp.*) and bean weevils. The latter is mostly common in storage (Allen et al., 1996; Msuku et al*.,* 2000; Banjo et al., 2003). The crop is also widely susceptible to diseases such as Bean Common Mosaic Virus (BCMV), Angular Leaf Spot (ALS), Bean root rot, Common Bacterial Blight (CBB), anthracnose and halo blight (Chiumia et al*.,* 2003; Mwang'ombe et al., 2008). Low and unstable yields are the most pertinent problems in common bean production in Malawi (Kadyampakeni, 2004; Mloza-Banda et al*.,* 2003). This occurs because most varieties grown under farmers' field conditions produce yields of less than 400 kg/ha which is far too low to meet the country's yearly growing demand (Mloza-Banda et al., 2003).

Bean production is categorized into three agro-ecological zones in Malawi based on altitude and rainfall patterns. The first is high altitude, high rainfall bean agro-ecological zone. The zone covers altitude greater than 2000 m above sea level (masl) and rainfall greater than 1500 mm per annum. Areas in the zone include part of Mulanje, Zomba and Thyolo districts among others. The second is the medium altitude, moderate rainfall bean agro-ecological zone. This zone covers most parts of central region of Malawi. Altitude ranges from 1000 to 2000 masl and rainfall between 800 and 1500 mm per annum. The third zone is high altitude, low rainfall bean agro-ecological zone which has altitude of over 2000 masl and rainfall below 800 mm per annum. The areas include most of the Northern region of Malawi (Wortmann et al., 1998; Mwale et al., 2008).

Currently, the available bean varieties do not grow in all bean-growing areas of Malawi. CIAT (1998) reported varieties that are well suited to specific locations. Napilira, Sapatsika, Kambidzi and Mkhalira grow in highland areas (1400 masl) with prolonged rainfall averaging 1000 mm per annum while Nagaga is suitable for medium altitude plains (1200 masl) with average rainfall of 800 mm per annum. The variation in adaptation limits some farmers who would be interested to grow certain common bean varieties in a particular area but are restricted by the instability of the bean yields across different environments.

There is need for plant breeders to develop common bean varieties that are stable in yield under farmer's conditions. The varieties should be able to suit a wide range of Malawi's agro ecological zones but most of all the varieties should be high yielding with minimal inputs such as inorganic fertilizers and chemicals for pests and disease control which are the most limiting production requirements to small scale farmers of Malawi.

In trying to address low and unstable bean yields which are one of the challenges; an on-farm study was conducted in 2003-2004 and 2004-2005 growing seasons under rain-fed condition in five sites representing three bean agro-ecological zones of Malawi. The study was aimed at evaluating on-farm performance of climber bean lines and identifying stable lines in the different bean agro-ecological zones of Malawi.

MATERIALS AND METHODS

Site selection

The research was conducted in 2003-2004 and 2004-2005 growing season. During the first growing season, bean entries were evaluated at five different sites representing three bean agro-ecological zones of Malawi (Table 1). These were: Ng'onga and Ntchenachena in Rumphi district representing high altitude and low rainfall agro-ecological zone; Thondwe in Zomba district and Matapwata in Thyolo district representing high altitude and high rainfall bean agro-ecological zones and Chipuka in Ntchisi district representing medium altitude and moderate rainfall agro-ecological zone (Figure 1). When the trial was repeated in the second growing season of 2004-2005, three sites were used, each site representing a particular agro-ecological zone as follows: Ntchenachena in Rumphi district representing high altitude, low rainfall agro-ecological zone; Chipuka in Ntchisi representing medium altitude, moderate rainfall agro-ecological zone and Matapwata in Thyolo representing high altitude, high rainfall agro-ecological zone.

The trial used seven bean germplasm; three were sourced from Bunda College namely BCMV B4, AND 659 and DC 86-244 while CAB 19, RWV 1046, RWV 1042-2-3 and 5P/5 were sourced from Chitedze Agricultural Research Station.

Selection of farmers and planting

Five farmers were randomly selected to host on-farm trials in each of the five sites. A primary criterion for selection was that farmers must have been growing beans for a minimum of 5 years. Selection of farmers in each site included female-headed households. Two female headed households and three male headed households conducted the trials in Matapwata and Chipuka while four female

Figure 1. Map of Malawi showing sites of beans trials.

headed households and one male headed household carried out the trials in Thondwe. In Ntchenachena, the trials were conducted by two male headed households and three female headed households. Following the selection process, farmer training was conducted in all the sites where the trials were located. The training covered management practices of the trials, expected outputs and impacts of their participation in the trials.

The planting dates were determined depending on days when adequate first rains were received in each of the sites. During 2003-2004 growing season, farmers in Ngong'a and Ntchenachena planted bean entries on 2nd and 3rd December, 2003, respectively. In Chipuka, farmers planted on 10th of December, 2003 while in

Matapwata and Thondwe planting of the entries was conducted on 26th and 27th November, 2003, respectively. During 2004 -2005 growing season, farmers in Ntchenachena planted the bean entries on 22nd December, 2004 while planting in Matapwata and Chipuka sites was done on 29th November, 2004. During planting, one seed was planted at a depth of 2-3 cm along the top of the ridged row.

Experimental design and treatments

Bean evaluation used Researcher Designed Farmer Managed (RDFM) system. In this system, farmers in each site conducted trials that were designed and laid out by the researcher. Seven best yielding climber bean entries collected from advanced trials conducted at the source stations over two seasons were evaluated on-farm for their yield performance and stability across the three agro-ecological zones of Malawi.

The trials were in Randomized Complete Block Design (RCBD) with two replications at each farmer's trial area. The two replicates were arrived at due to scarcity of land as most farmers were reluctant to allocate a larger piece of land for the trials. Seven treatments, which were BCMV B4, AND 659, DC 86-244, CAB 19, RWV 1046, RWV 1042-2-3 and 5P/5 were allocated to each replicate. A replicate comprised three rows each of 5 m long. Each farmer was required to choose a field that measured 12 by 12 m to accommodate the trial. A one-metre wide path was demarcated through the middle of the field and all around the field was a path measuring 0.5 m wide. A total of twenty-one rows each measuring 5 m in length were marked on either side of the center path. The distances between the row centers and planting stations in a row were 0.75 m and 10 cm, respectively. Farmers were advised to weed regularly but not apply fertilizers or chemicals to the entries. Three weeks after germination, farmers were advised to stake their plots to allow proper growth of the climber entries in stakes.

Data collection and analysis

Data collection was done at the net plot which comprised the middle row of each treatment plot excluding 0.5 m on either side of the middle row. Data collection included number of days to physiological maturity, 100 seed wet weight (grams), 100 seed dry weight (at 10% moisture content) in grams, total yield (grams) from all seeds collected from the net plot. This set of data (except days to physiological maturity) helped to estimate yield in kilograms per hectare using standard formula:

$$\frac{DM_1(g)}{DM_2(g)} x \frac{Net\ plot\ yield\ (g)}{1000g} x \frac{10000\ m^2}{Plot\ size\ (m^2)}$$

Where DM_1 = Dry matter after harvest and DM_2 = Dry matter at 10% moisture content.

Genstat computer package was used to analyze the estimated data. Pest and disease incidences (not reported) were also scored. Rainfall data was collected throughout the trial period. Government agricultural extension workers assisted in data collection on each and every farmer's field throughout the research period.

Additive Main effect and Multiplicative Interaction (AMMI) model (Gauch, 1993) was used for testing the stability of the bean lines. This model is more efficient in determining the most stable and high yielding genotypes in multi-environment trials compared to other methods. Egesi and Asiedu (2002) reported that the model uses the analysis of variance (ANOVA) approach to study the main effects of genotypes and environments. It also uses an Interaction Principal Component Analysis (IPCA) for the residual multiplication interact-tion between genotypes and environments.

Genotypes with IPCA scores near zero show little interaction across environments depicting stable characteristics (Carbonell et al., 2004). Genotypes and environments combinations with IPCA scores of the same sign produce positive specific interaction effects, whereas combinations of opposite signs have negative specific interactions. Genotypes appearing to the right side of vertical ordinates for grand mean yield are high yielding while those to the left are low yielding hence below average performance (Egesi and Asiedu, 2002; Manrique and Hermann, 2000; Abidin et al., 2005).

RESULTS AND DISCUSSION

The results from first and second seasons showed significant differences between the number of days to physiological maturity in different bean entries. In Ntchenachena, RWV 1042-2-3 and BCMV B4 were the earliest maturing bean entries in 83.3 and 84.0 days respectively. In Ng'onga, AND 659 and DC 86-244 matured early in 74.8 and 74.3, days respectively in addition to BCMV B4 which matured in 74.9 days. Similar trend was recorded in Chipuka Thondwe and Matapwata where BCMV B4, DC 86-244 and AND 659 matured early compared to other bean entries in 2003-04 growing season (Table 2).

In 2004-2005 growing season, bean entries matured very early in the two sites where data was collected compared to previous year. The earliest maturing varieties were 5P/5 and DC 86-244 which matured in 71.5 and 72.9 days, respectively in Ntchenachena. The entries also matured early in Chipuka compared to other entries in the site as they reached maturity in 91.0 and 91.7 days, respectively but were not significantly different to CAB 19 and AND 659 that matured in 89.0 and 90.5 days, respectively. Entry RVW 1042-2-3 though matured early in Ntchenachena (in 83.0 days) was the longest to mature in Chipuka as it took 94.5 days of maturity (Table 2). It is advantageous for common beans to have traits of shorter maturity since most farmers prefer varieties that mature in shorter time compared to longer days to maturing (Mloza-Banda et al., 2003). Hence entries DC 86-244, AND 659 and BCMV B4 that matured early in most locations stand a possibility of more preference compared to other entries in the trials.

The longest period of maturity in 2003-2004 growing season was recorded in CAB 19 and RWV 1046 across the sites. CAB 19 was the longest maturing entry in Ntchenachena, Ng'onga, Chipuka, Thondwe and Matap-wata in 94.6, 83.3, 83.0, 84.5 and 82.4 days, respectively (Table 2). RWV 1046 was the longest maturing entry in Ng'onga, Chipuka, Thondwe and Matapwata as it took 83.6, 83.7, 83.7 and 82.7 days, respectively, while in Ntchenachena, the entry was second longest maturing entry in 89.3 days (Table 2). In 2004-2005 growing season, AND 659, CAB 19, BCMV B4 AND RWV 1046 were longest maturing entries in Ntchenachena maturing in 78.1, 76.8, 76.5 and 75.4 days but the number of days were considerably lower compared to the previous season where the longest maturing bean entries took over eighty days to mature. In Chipuka, the entries RWV

Table 2. Number of days taken by climber bean entries to physiological maturity.

Entries	Ntchenachena		Ng'onga		Chipuka		Thondwe		Matapwata	
	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05[2]
CAB 19	94.6^{e}	76.8^{bc}	83.3^{c}		83.0^{b}	89.0^{a}	84.5^{d}		82.4^{cd}	
RWV 1046	89.3^{d}	75.4^{abc}	83.6^{c}		83.7^{b}	94.2^{c}	83.7^{d}		82.7^{d}	
RWV 1042-2-3	83.0^{a}	72.4^{ab}	80.8^{bc}		84.1^{b}	94.5^{c}	79.1^{c}		80.3^{bcd}	
5P/5	86.8^{cd}	71.5^{a}	79.1^{b}		85.3^{b}	91.0^{abc}	77.9^{c}		80.3^{bcd}	
AND 659	88.0^{cd}	78.1^{c}	74.8^{a}		77.6^{a}	90.5^{ab}	73.5^{a}		75.6^{a}	
DC 86-244	85.8^{bc}	72.9^{ab}	74.5^{a}		76.1^{a}	91.7^{abc}	77.3^{bc}		78.8^{abc}	
BCMV B4	84.0^{ab}	76.5^{bc}	74.9^{a}		74.1^{a}	92.7^{bc}	75.4^{ab}		78.6^{ab}	
CV %	5.9	7.2	4.5		7.3	3.2	4.9		5.3	
LSD	2.7	4.9	3.2		5.2	3.5	3.4		3.8	
Sign	***	**	***		***	**	***		**	

NB: Means with similar letters in the same column are not significantly different.
*Significant at 5%, ** significant at 1%, *** significant at 0.1%. 1, Trials were not conducted during the season hence no data was collected. 2, No data was recorded in the season as bean entries got scorched by dry spell.

1042-2-3 and RVW 1046 were the longest maturing entries in 94.5 and 94.2 days, respectively (Table 2). The entry RVW 1046 was equally late maturing in 2003-2004 growing season in most of the trial sites.

Except for few entries that matured later than 90 days during 2003-2004 growing seasons, the results found in this research on number of days to physiological maturity are similar to findings by Kadyampakeni (2004), Stoilova et al. (2005) and Chataika (2006) who reported that most of the common bean entries they researched on matured in periods ranging from 71.7 to 86.3 days.

Significant differences were recorded on seed size of climber bean entries in two sites namely Ntchenachena and Ng'onga. DC 86-244 and AND 659 had largest seed sizes in Ntchenachena and Ng'onga in 2003-2004 season of 35.5, 29.8 g/100 seeds and 45.0, 40.5 g/100 seeds, respectively (Table 3). In 2004-2005 growing season the same bean entries had largest seed sizes in Ntchenachena. DC 86-244 recorded 30.8 g/100 seeds while AND 659 had 28.5 g/100 seed sizes. Both entries had significant larger seed sizes compared to the rest of the bean entries.

Chataika (2006) reported that most farmers prefer large seeded bean varieties since they fetch high prices on the markets compared to small seeded varieties though in some cases the seed coat colours can also influence farmers' preference. Similar observations were also reported by Bucheyeki et al. (2008) who indicated that during their selection of new varieties, farmers in Tanzania use seed size as one criterion and large seed sizes are preferred for production. It is, therefore, likely that entries DC 86-244 and AND 659 may be preferred by farmers due to their large seed sizes as demonstrated in the trials. Smallest seed size was recorded in CAB 19, RWV 1046, 5P/5 and RWV 1042-2-3 in 2003-2004 season of 21.5, 22.4, 24.3, 25.1g/100 seeds, respectively in Ntchenachena while similar entries, with exception of 5P/5, had smallest seed size in Ng'onga of 28.5, 29.5 and 27.0 g/100 seeds, respectively. During the 2004-2005 growing season, same bean entries recorded smallest seed sizes in Ntchenachena (Table 3).

However, no significant differences were observed in seed sizes for all bean entries in Chipuka, Thondwe and Matapwata sites during 2003-2004 and 2004-2005 growing seasons. All bean entries in Matapwata during 2004-2005 growing season did not survive the trials. Heavy rains and subsequent dry spell that followed soon after planting (Table 5) destroyed all bean entries in all the farmers' fields as such the trial was abandoned in the site. Since Thondwe site, which falls in the same agro-ecological zone was not used on the onset in 2004-2005 growing season due to logistical problems, the whole agro-ecological zone did not record any data for climber entries.

There were significant differences in yield of climber entries in all the sites during 2003-2004 growing season. DC 86-244 was highest yielding entry in Ntchenachena, Ng'onga and Chipuka yielding 990, 1399.2 and 1314.7kg/ha respectively. The entry was not significantly different with RWV 1046 in Ng'onga and RVW 1042-2-3 in Thondwe which yielded 1314 kg/ha and 1155 kg/ha respectively (Table 4). CAB 19 was the highest yielding in Matapwata with yield of 663.7 kg/ha. BCMV B4 was the lowest yielding climber entry in 2003-2004 grow-ing season across the sites. The entry failed to yield above one tonne in all the sites and the highest yield was 778.4 kg/ha attained in Thondwe during 2003-2004 growing season.

Lower yields were recorded in 2004-2005 growing seasons. All bean entries yielded below one tonne in the two sites where data was recorded. There was no significant difference between entries in Ntchenachena. This indicated that all entries yielded similarly in the site despite significant differences recorded in seed size in the site

Table 3. Seed size (g/100 seeds) of climber bean entries in 2003-04 and 2004-05 growing season.

Entries	Ntchenachena		Ng'onga		Chipuka		Thondwe		Matapwata	
	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05[2]
DC 86-244	35.5^{c}	30.8^{b}	45.0^{e}		42.3	31.0	30.5		30.2	
AND 659	29.8^{bc}	28.5^{b}	40.5^{de}		32.4	24.3	30.0		29.2	
BCMV B4	22.0^{a}	22.3^{a}	36.5^{cd}		32.0	30.5	29.0		26.4	
RWV 1042-2-3	25.1^{ab}	23.1^{a}	27.0^{a}		32.5	28.0	31.5		27.9	
5P/5	24.3^{ab}	21.8^{a}	33.5^{bc}		33.5	19.0	31.4		30.4	
RWV 1046	22.4^{a}	24.1^{a}	29.5^{ab}		29.6	25.4	27.5		27.3	
CAB 19	21.5^{a}	21.2^{a}	28.5^{a}		31.8	25.1	27.8		29.7	
CV %	28.0	17.6	13.9		27.4	31.0	23.4		27.5	
LSD	6.4	4.1	4.4		17.6	13.4	6.2		6.9	
Sign	**	***	***		NS	NS	NS		NS	

NB: Means with similar letters in the same column are not significantly different. *Significant at 5%, ** significant at 1%, *** significant at 0.1%. 1, Trials were not conducted during the season hence no data was collected. 2, No data was recorded in the season as bean entries got scorched by dry spell.

Table 4. Yield (kg/ha) of climber entries in 2003-04 and 2004-05 growing seasons.

Entries	Ntchenachena		Ng'onga		Chipuka		Thondwe		Matapwata	
	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05[2]
DC 86-244	990.0^{d}	221.0	1399.2^{c}		1314.7^{c}	297.0^{ab}	1055.1^{cd}		484.0^{cd}	
RWV 1046	651.9^{b}	254.0	1314.6^{c}		998.4^{b}	342.0^{ab}	795.5^{ab}		564.7^{d}	
5P/5	747.1^{c}	174.0	769.6^{b}		1011.1^{b}	557.0^{b}	708.0^{a}		398.6^{abc}	
RWV 1042-2-3	521.8^{a}	173.0	1056.0^{b}		627.4^{a}	402.0^{ab}	1155.0^{d}		425.3^{bc}	
CAB 19	710.2^{b}	203.0	729.8^{a}		665.7^{a}	391.0^{ab}	971.5^{bc}		663.7^{e}	
AND 659	735.7^{bc}	232.0	714.3^{a}		980.3^{b}	218.0^{a}	928.0^{bc}		388.7^{ab}	
BCMV B4	524.9^{a}	178.0	716.6^{a}		753.3^{a}	294.0^{ab}	778.4^{ab}		337.0^{a}	
CV %	46.8	58.9	29.2		23.3	64.9	35.4		63.1	
LSD	92.0	104.5	110.0		144.4	293.2	166.5		85.9	
Sign	***	NS	***		***	*	***		*	

NB: Means with similar letters in the same column are not significantly different. *Significant at 5%, ** significant at 1%, *** significant at 0.1%. 1, Trials were not conducted during the season hence no data was collected.
2, No data was recorded in the season as bean entries got scorched by dry spell.

Table 5. Monthly rainfall collected during 2003-2004 and 2004-2005 growing seasons in five and three trial sites respectively.

Month	Ntchenachena		Ng'onga		Chipuka		Thondwe		Matapwata	
	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05	2003-04	2004-05[1]	2003-04	2004-05
October	39.0	0.0	0.0		0.0	0.0	0.0		37.0	6.0
November	9.9	0.0	0.0		11.4	149.2	130.8		177.1	80.2
December	138.9	51.9	197.6		168.5	350.6	297.9		66.6	469.3
January	199.1	200.3	52.3		168.6	98.6	190.8		160.6	36.0
February	267.6	180.1	108.1		184.4	75.9	200.2		127.8	27.1
March	215.5	238.7	135.8		149.8	61.0	150.6		111.9	56.5
April	0.0	16.0	0.0		70.9	0.0	199.4		138.2	57.5
May	9.4	11.2	0.0		0.0	0.0	154.7		231.0	59.2
June	9.4	5.4	0.0		47.0	13.0	45.0		65.0	39.6
July	0.0	0.0	0.0		0.0	0.0	56.0		49.3	0.0
August	0.0	0.0	2.4		0.0	0.0	12.0		7.6	0.0
September	1.9	0.0	2.4		0.0	0.0	12.0		7.6	0.0

NB: 1 Trials were not conducted during the season hence no data was collected.

during 2004-2005 growing season (Table 3). 5P/5 is the only entry that yielded above half of a tonne (557.0 kg/ha). Due to environmental factors, all bean entries in Matapwata were destroyed during 2004-2005 growing season. The site received very high amount of rains of 469.3 mm immediately after planting in December 2004. The rains destroyed some bean entries during the month though some entries survived. The heavy rains were followed by dry spells during January and February 2005 and lowest rains reading 36.0 and 27.1 mm respectively were recorded (Table 5). This scenario wiped all the bean entries that survived the initial effect of heavy rains. As such the trial was abandoned.

Rosales-Serna et al. (2000) reported that common beans yields are drastically reduced when dry spells and erratic rainfall occur in a growing season. They also reported that reproductive stages such as flowering and pod filling are very critical in water requirements such that total crop loss can result from this water shortage. Mwale et al. (2008) also reported drastic reduction in yield due to low moisture levels during flowering and pod filling of dwarf beans but in most cases, drought stress is more pronounced in climber varieties compared to dwarf bean varieties (Chataika, 2006). It is, therefore, not surprising that trials in Matapwata were wiped due to dry spells that occurred during the second season. White and Singh (1991) observed 20% yield reduction due to drought stress during early or late vegetative growth, 50% reduction in early pod fill and no reduction in late pod fill. Apart from dry spells and erratic rainfall, environmental factors such as low or high temperatures can also cause complete destruction of common beans (Rosales-Serna et al., 2001).

AMMI analysis of variance for the advanced climber bean yield indicated significant differences (P<0.001) between sum of squares for treatments, genotypes, environments and interaction between genotype and environment (Table 6). Genotypes accounted for 7.5% of the treatments sum of squares while environments accounted for 74.3%. This showed a greater influence that environment had on variations of yield in the trials. Interactions between genotypes and environments accounted for 18.2% for mean sum of squares. This meant that there was substantial influence on genotypic expression from environmental differences from one location to another.

When the interactions were split into principal component one and two (IPCA 1 and 2), analysis indicated a greater percentage of 48.7% for sum of squares explained by Interaction Principal Component Analysis one (IPCA 1) compared to 30.0% for IPCA 2 (Table 6). As such biplot for IPCA 1 against interaction for genotype and environments was used to determine influence of environments on genotype performance and establish stable entries across the environments. 21.3% was accounted for residuals or noise of the treatment sums of squares and it showed that the model was able to explain 78.7% of the treatment sums of squares.

Genotype G1 (CAB 19) and G7 (DC 86-244) were very stable across the environments in both first and second seasons. This was due to very low scores on IPCA scales as they were close to zero line on X ordinates (Figure 2) since according to Rodríguez-Pérez et al. (2005), the genotypes close to intercept as well as zero line on X ordinates are the most stable and as they move away from the zero line and intercept, behavior of genotypes becomes more variable. DC 86-244 was also high yielding entry across environments since it was on extreme right side of the IPCA biplot (Manrique and Hermann, 2000). G3 (BCMV B4) was fairly stable but lowest yielding climber entry across environments and seasons. G1 (CAB 19), G5 (RWV 1042-2-3) and G6 (5P/5) were average yielding climber entries as they fell along average y line on the biplot (Figure 2) but RWV

Table 6. AMMI analysis of variance for yield of climber entries.

Source of Variation	Degrees of freedom (df)	Sums of Squares (SS)	Mean squares (MS)	Explained %
Total	293	45009593	153616	
Treatments	48	31531235	656901***	
Genotypes	6	2360913	393486***	7.5
Environments	6	23437631	3906272***	74.3
Block	14	590222	42159	
G and E Interactions	36	5732691	159241***	18.2
IPCA 1	11	2792167	253833***	48.7
IPCA 2	9	1717049	190783***	30.0
Residuals	16	1223475	76467	21.3
Error	231	12888136	55793	

***Significant at 0.1%.

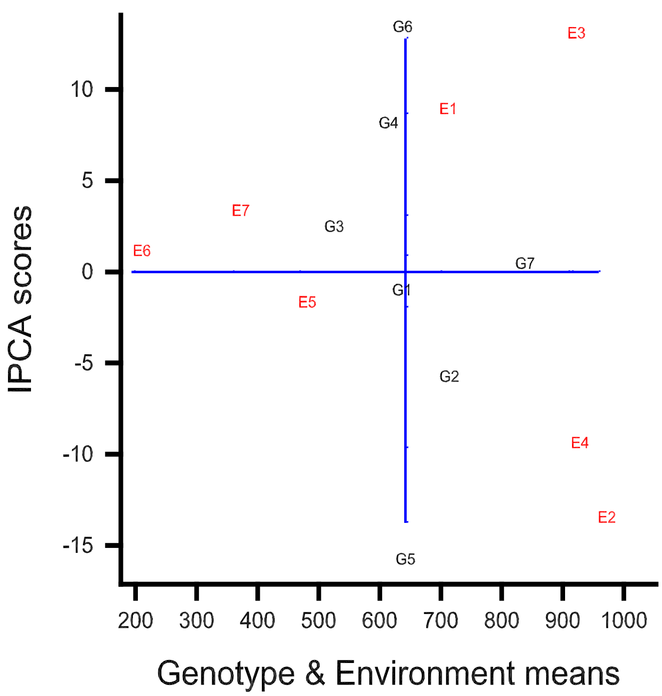

Figure 2. Biplot of climber genotype and environment IPCA 1 versus mean yield (kg/ha) of seven genotypes and seven environments. Genotypes: G1, CAB 19; G2, RWV 1046; G3, BCMV B4; G4, AND 659; G5, RWV 1042-2-3; G6, 5P/5; G7, DC 86-244. Environment: E1, Ntchenachena 2003-04; E2, Ngong'a 2003-04; E3, Ntchisi 2003-04, E4, Thondwe 2003-04; E5, Matapwata 2003-04; E6, Ntchenachena 2004-05; E7, Ntchisi 2004-05.

1042-2-3 and 5P/5 were very unstable entries in the trials since they were found on extreme positive and negative IPCA scores ranges respectively on the biplot (Abidin et al., 2005).

Environments E6 (Ntchenachena 2004-2005 season) was the most stable environment but it was extremely low yielding of all the environments (Figure 2). E5 (Matapwata 2003-2004) was also stable environment for bean production though it was below average in yield performance for the climber entries. Due to unpredictable rainfall pattern in the site as observed during 2004-05 season (Table 5), the site can not be recommended for suitability to climber bean production unless more observations are made. E2 (Ng'onga 2003-04), E3 (Ntchisi 2003-04) and E4 (Thondwe 2003-04) were unstable but high yielding environments for climber bean entries. According to Egesi and Asiedu (2002), the three sites could be best used for selection of genotypes with high yielding traits.

Conclusion

The trial identified bean entries that demonstrated various characteristics ranging from early maturing, large seed sizes, high yielding to stability traits across sites and agronomic seasons of on-farm trials despite changes in environmental characteristics such as rainfall over the two growing seasons. Entries DC 86-244, AND 659 and BCMV B4 demonstrated early maturity traits in most sites of the trial. DC 86 244 and AND 659 were also high yielding and had larger seed sizes compared to other entries in most sites in both seasons of the trials. Other entries such as RWV 1046 and RVW 1042-2-3 were also high yielding, though had smaller seed sizes. Stability analysis identified entries CAB 19 and DC 86 244 as stable entries across sites and seasons. These early maturing, high yielding and stable entries may be recommended for further evaluation that may lead to their release for production by farmers in Malawi. Among environments, Ng'onga, Chipuka and Thondwe were high yielding. Ntchenachena was more stable but lower yielding compared to other sites. Matapwata was highly unreliable as heavy rains followed by dry spells characterised the site which resulted in loss of all bean entries in 2004-2005 growing season.

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