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Fresh Pod Yield and Stability of NSIC-Approved Varieties of Pole Snap Bean (*Phaseolus vulgaris* L.) in Benguet

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Abstract

Snap bean production is one of the main sources of livelihood of farmers in Benguet. It is mainly grown for fresh pods which can produce 17 to 28 t/ha depending on the cultivars. Snap bean farmers largely depend on the use of traditional variety which is low yielding with inferior pod quality. The BSU-IPB HCRS at BSU has developed and registered new improved varieties for production in the Northern Philippine Highland and officially approved by the DA-BPI NSIC for commercialization. On-farm trials involving eight varieties of pole snap beans were set up in four municipalities of Benguet following RCBD with three replications. The study aimed to evaluate the fresh pod yield, stability of NSIC-approved pole snap bean varieties, determine the most suitable location, identify the most stable and adapted variety for production in Benguet. The fresh pod yield of the eight pole snap bean varieties evaluated differed significantly among each other in four municipalities. Across locations, varieties 'Itogon' and 'Kapangan' produced the highest marketable fresh pod yield while variety 'Itogon' recorded the heaviest total fresh pod yield. Pole snap beans grown in Kapangan produced the highest marketable and total fresh pod yield. Significant interaction effect of genotype and environment was observed in the fresh pod yield. 'Tublay' was the most stable variety based on total fresh pod yield. Variety 'Kibungan' had specific adaptability in Kapangan and La Trinidad. Varieties 'Mabunga' and 'Itogon' had specific adaptability in Sablan and Varieties 'Wangal,' 'Tuba,' 'Alno,' 'Tublay,' and 'Kapangan' are best grown in Kibungan.

Introduction

Local production of vegetables is observed to be decreasing which consequently reduced local supply based from the 2010-2020 Philippine Statistics Authority (PSA) data. Besides the effect of erratic climatic conditions, this is mainly due to the lack of desirable varieties that are high yielding with resistance and good eating qualities. Snap bean (*Phaseolus vulgaris* L.) is a versatile nutritious specialty vegetable crop not only in the Northern Philippine highland but to the whole country as well. It belongs to the top vegetable crops produced in Cordillera Administrative Region (CAR) (Office of Provincial Agriculturist [OPAG], 2017). At present, around 70% of vegetable supply in the country is produced in Benguet and others are coming from nearby areas. Vegetable farmers are still highly dependent on traditional varieties that are low yielding and susceptible to

their major pests and diseases with inferior pod quality. The improved desirable varieties of pole snap beans that are high yielding with resistance to pests and diseases and better qualities were already developed at Benguet State University. These varieties have not fully reached the farmers that grow the crop. For the farmers to observe and have an idea of the fresh pod yield potential of new NSIC-registered varieties for commercialization, this study was undertaken to enhance vegetable production and consumption among Filipinos; sufficient and affordable high yielding and nutritious varieties must be available to the farmers and consumers.

Snap bean area for cultivation from 2002 to 2022 was recorded in the following province: in Benguet, 649 to 654 ha, in Ifugao, 392-203 ha and in Mt. Province, 173 to 90 ha and in the Cordillera alone, the total area of production was from 3770.02 to 3042.09 ha (PSA, 2023). These show that there is a need to produce the required volume of seeds to sustain snap bean production and to reduce dollar expenditure on seed importation. The conventional practice of farmers is to keep part of their harvest for seeds. However, seed crops also carry diseases and pests resulting in reduced yield and quality.

Genotype x environment interaction (GEI) continues to be a challenging issue among plant breeders, geneticists, and production agronomists who conduct crop performance trials across diverse environments (Rao & Prabakaran, 2003). Recently, fresh pod yield stability as a selection trait in plant breeding programs and evaluation trials is constantly gaining importance especially in developing countries where the number of small and marginal farmers with small holding is very high. One main strategy among small-scale subsistence farmers is to grow improved variety with stable yield which is the key to sustainable food supply.

In the Philippines, State Universities and Colleges (SUCs) are also mandated to produce seeds of inbred lines and open pollinated varieties (OPVs) to supply the needs of consuming public and government programs as well as other markets that will not directly compete with the private sector. As of now, the government programs are buying seeds, usually hybrids from private seed companies. In doing so, it is promoting the varieties of the private sector that are not "recyclable". This project covers the evaluation of public inbred varieties, which can be more sustainable for farmers.

The joint breeding program conducted at the Benguet State University–Institute of Plant Breeding Highland Crops Research Station (BSU-IPB HCRS) got final approval of the National Seed Industry Council (NSIC) for their seven new improved varieties of pole snap bean in 2008, 2009 and 2016 as new official varieties registered and released for commercialization in the Cordillera Administrative Region (Tandang et al., 2010). Since snap bean growers still use commonly grown traditional varieties that are low yielding with inferior pod quality and susceptible to major pests and diseases, it is necessary to introduce to them the new NSIC-approved improved varieties of this leguminous crop for commercialization through on-farm trials in farmers' fields. On-farm trial is also called promotional trial that should be conducted in major growing areas of the crop in the Northern Philippine highland particularly in the province of Benguet where pole snap beans are commercially grown.

This paper presents the result of on-farm trials for fresh pod yield evaluation and stability of NSIC-approved varieties of pole snap bean in four municipalities of Benguet and identifies the most suitable location, stable and adapted varieties for pole snap bean production in the province of Benguet.

Materials and Methods

Seven NSIC-approved varieties of snap bean developed and identified in the Varietal Improvement Program of Semi-Temperate Vegetable Crops undertaken at the BSU-IPB HCRS (Tandang et al., 2010) together with the commercial traditional variety grown by the farmers in Benguet were considered as the test materials in the on-farm trials undertaken in two years from 2018-2020 in four municipalities of Benguet. Testing sites were identified based on area and volume of production obtained from the LGU Benguet Statistics and Provincial Profile of Benguet (Benguet Province-Local Government Unit, 2009). The project proponent made necessary arrangements with respective authorities

and prospective partners in the provincial and municipal LGUs of Benguet ahead of time before the actual conduct of the on-farm trials. Cooperating farmers in four municipalities were also selected and identified based on accessibility and sufficiency of the area, and willingness of the farmer to share his farm resources. Seeds needed in the trial in each location and technical assistance were provided by the researcher to ensure successful conduct of on-farm trials in each municipality.

Field Layout and Experimental Design

The on-farm trial (OFT) was set up in each of the four municipalities of Benguet namely La Trinidad, Sablan, Kapangan and Kibungan (Figure 1). The OFT involved eight pole snap bean varieties as treatment namely, varieties 'Kapangan', 'Tublay', 'Kibungan', 'Wangal', 'Tuba', 'Mabunga', and 'Itogon' as test varieties which were developed at BSU-IPB HCRS at BSU and officially approved and registered for commercialization by the National Seed Industry Council (NSIC) of the Department of Agriculture-Bureau of Plant Industry (DA-BPI) and 'Alno,' the traditional variety commercially grown by the farmers in Benguet served as the check variety. The trial was set up following Randomized Complete Block Design (RCBD) with three replications. Each variety was planted in a double row 10m² plot at a distance of 25cm x 25cm between hills and between rows. All farmers' practices were followed in respective locations.

Data Collection

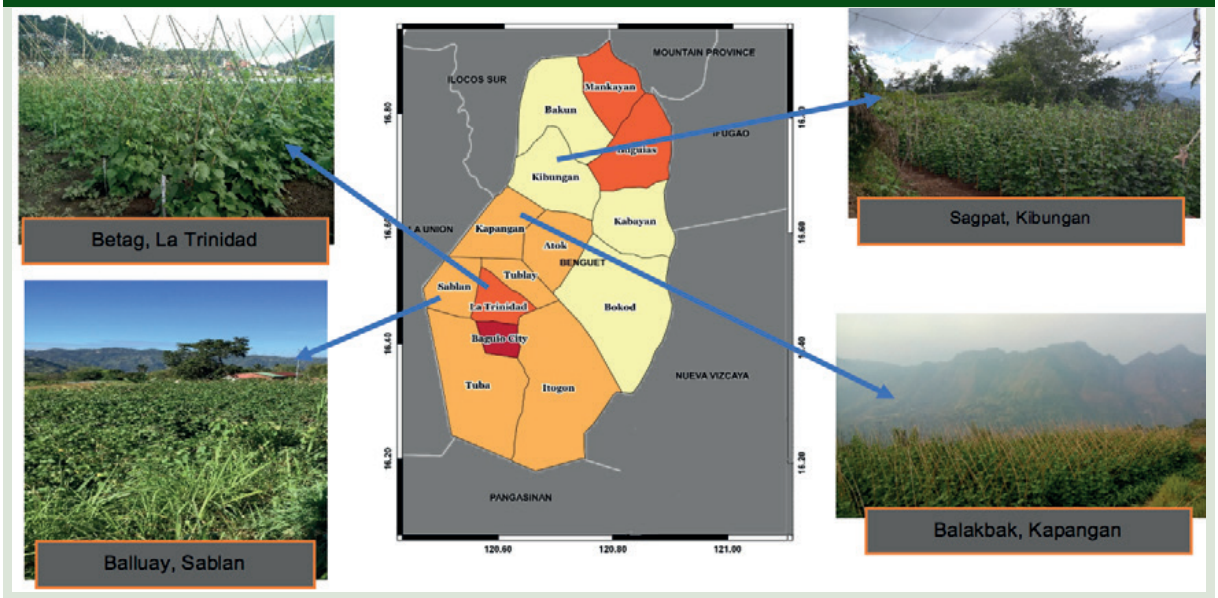
Marketable and total fresh pod yield per plot (kg/10m²) were gathered by weighing the marketable and total fresh pods per plot every harvest. Their respective sum was computed after the last harvesting in each location.

Data Analysis

The gathered data were analyzed using the analysis of variance (ANOVA) for RCBD with three replications in each test location. The significance of differences among the treatment means was determined using the Least Significant Difference Test (LSD) at 5% level of significance. Combined Analysis of Variance was used to analyze the total fresh pod yield data among varieties (Genotype, G) tested across locations (Environment, E) and determine the G x E interaction effect on pole snap bean yield. The Additive Main Effects Multiple Interaction (AMMI) was used for the data on total fresh pod yield per plot to determine the stability in yield performance of the varieties of pole snap bean

Figure 1

Map Showing On-Farm Trial (OFT) Sites for Pole Snap Bean in Four Municipalities of Benguet



evaluated in different locations using the following model (Gauch & Zobel, 1997):

$$Y_{ger} = \mu + \alpha_g + \beta^e + \sum_n \lambda_n \gamma_{gn} \delta_{en} + \rho^{ge} + \sum_{ger}$$

where:

Y_{ger} : Yield of genotype (g) in environment (e) for replicate (r)

μ	-	grand mean
αg	-	genotype deviation
β^e	-	environment deviation
$\sum_n \lambda_n \gamma_{gn} \delta_{en}$	-	eigenvectors
λ_n	-	singular value for PCA axis n
γ_{gn}	-	genotype eigenvector
δ_{en}	-	environment eigenvector
ρ^{ge}	-	residual
$\sum_{ger}$	-	error term

AMMI 1 and AMMI 2 and their biplots were generated. AMMI 1 biplot has mean effects on the abscissa and first Interaction Principal Component Analysis (IPCA 1) score on the ordinate while AMMI 2 retains 2 IPCA axes. Biplots were generated using GenStat 16th edition.

The above general equation:

AMMI 1 resulted in:

$$Y_{ger} = Tg + \Pi e + \mu - (\lambda^{0.5} \gamma_g) (\lambda^{0.5} \acute{\varepsilon}^e) + \sum_{ger}$$

where:

T_g	-	genotype mean
Π^e	-	environment mean
μ	-	grand mean
Λ	-	singular value for PCA axis
γg	-	genotype eigenvector
δen	-	environment eigenvector
ρ^{ge}	-	residual
Σ_{ger}	-	error term

while AMMI 2 equation resulted in:

$$Yger = \mu + \alpha^g + \beta^e + (\lambda^{0.5} \gamma^{g1}) (\lambda^{0.5} \acute{\varepsilon} e1) + (\beta^e \lambda^{0.5} \gamma g^2) (\lambda^{0.5} \acute{\varepsilon} e^2) + \rho^{ge}$$

where:

μ	-	grand mean
αg	-	genotype deviation
β^e	-	environment deviation
Λ	-	singular value for PCA axis
γg	-	genotype eigenvector
δen	-	environment eigenvector
ρge	-	residual
μ	-	grand mean

Site Description

The following is the description of the environment of each evaluation site in four municipalities of Benguet (Figure 1):

Balakbak, Kapangan, Benguet is located approximately at 16.5321 Latitude, 120.6123 Longitude in the island of Luzon with an elevation estimated at 820 masl. The soil in Balakbak, Kapangan, Benguet has soil pH of 6.58, 2.05% Organic Matter (OM), 0.103% Nitrogen (N), 18.03ppm Phosphorus (P) and 190.33ppm Potassium (K) before planting. The area was planted with rice and was fallowed for three months before it was planted with pole snap bean.

Balluay, Sablan, Benguet is located 16.5321 Latitude, 120.5484 Longitude with an elevation estimated at 754 masl. The soil in Balluay, Sablan, Benguet has soil pH of 6.12 soil pH, 1.22% OM, 0.061% N, 62.35ppm P and 193.73ppm K. The area was planted with bell paper and was fallowed for almost one year before it was planted with pole snap beans.

Sagpat, Kibungan, Benguet is located approximately at 16.6640 Latitude, 120.6780 Longitude and the elevation at this coordinate is estimated at 1,548.00 masl. In Sagpat, Kibungan, Benguet, the area was previously planted with vegetable crops and was planted also with chayote before planting with pole snap bean. The soil before planting had soil pH of 4.82, 4.89% OM, 0.100% N, 61.68ppm P and 235.00ppm K.

In Betag, La Trindad, Benguet, the area is basically flat terrain with an estimated coordinates of 16.4553 Latitude and 120.584 Longitude and coordination at this estimate was 1,323 masl or 4340 feet above sea level. Mostly farmers are planting snap beans in the locality as their alternate crop.

Soil chemical properties of each location were analyzed at the Regional Soil Laboratory, San Fernando, La Union and the elevations were taken using google earth app via online.

Results and Discussion

Marketable and Total Fresh Pod Yield Per Plot (kg/10m²)

The marketable fresh pods of the eight pole snap bean varieties evaluated differed in the four municipalities of Benguet except in La Trinidad (Table 1). In Kapangan, Benguet variety 'Kibungan' produced the significantly heaviest marketable fresh pod which was comparable to those of 'Mabunga' and 'Itogon'. 'Alno,' the check variety had the least marketable fresh pods per plot. In Sablan, Benguet, variety 'Itogon' produced the heaviest marketable fresh pods while varieties 'Alno,' 'Wangal' and 'Kibungan' had the least marketable fresh pods. In Kibungan, Benguet, variety 'Kapangan' had the highest marketable pod/plot but it was comparable to the fresh pod yield of varieties 'Itogon', 'Mabunga,' and 'Wangal' while 'Alno' had the least marketable fresh pod yield. In La Trinidad, Benguet, fresh pod yield ranged from 6.15 to 9.23 kg /10m².

Across locations, varieties 'Kapangan' and 'Itogon' had the highest marketable fresh pod yield per plot. 'Alno,' the check variety had the least marketable fresh pod yield. Among locations, pole snap bean varieties planted in Kapangan had the highest marketable fresh pods followed by those planted in Kibungan and Sablan while those planted in La Trinidad produced the least marketable fresh pods. Significant interaction effect of variety and location on marketable fresh pod yield/plot was observed in pole snap beans (Figure 2). Varieties 'Kibungan,' 'Itogon,' 'Tublay,' 'Mabunga,' and 'Kapangan' produced the highest marketable fresh pod yield/plot when grown in Kapangan. In Sablan, varieties 'Itogon,' 'Kapangan,' and 'Mabunga' were the highest yielders. In Kibungan, varieties 'Kapangan,' 'Itogon' and 'Tublay' recorded the highest marketable fresh pod yield per plot and varieties 'Kapangan' and 'Mabunga' were the top yielders in La Trinidad. The different varietal response in different municipalities could be due to the influence of climatic conditions that differed in test locations that could be related to the different number of flowers and pods produced per cluster including different pod length and width in different environments.

In terms of total fresh pod yield/plot (kg/10m²), significant differences were observed among the varieties tested in each location except in La Trinidad (Table 1). In Kapangan, the variety 'Kibungan' had the heaviest total fresh pod yield which was comparable to the total yield of varieties

Figure 2

Interaction Effect of Variety (Genotype) and Location (Environment) on the Marketable Fresh Pod Yield/Plot (kg/10m²) of Pole Snap Bean

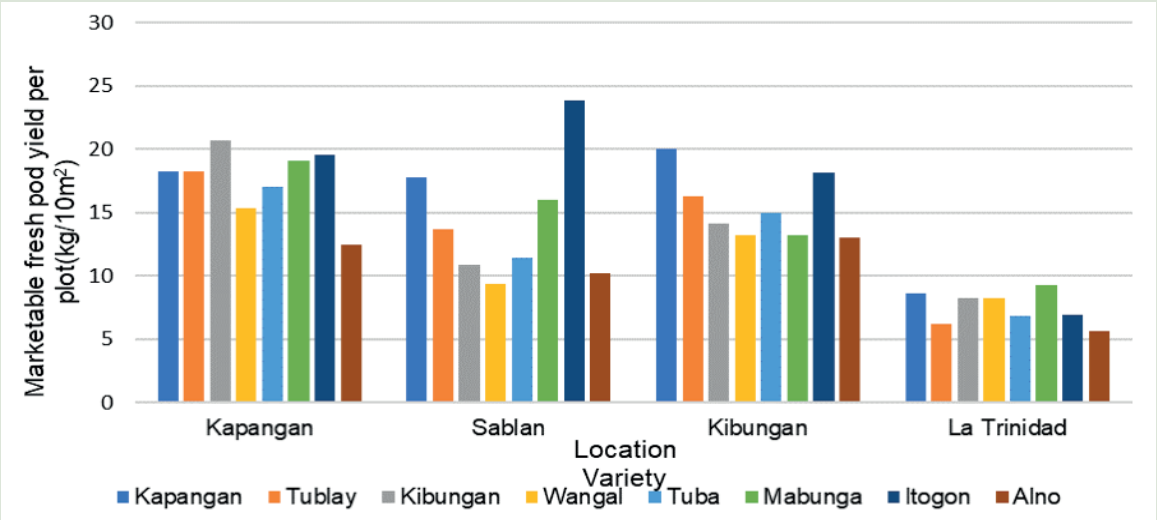


Table 1

Marketable and Total Fresh Pod Yield/Plot of the Eight Pole Snap Bean Varieties Grown in Four Locations in Benguet

Varieties	Fresh Pod Yield per Plot (kg/10m²)									
	Marketable				Mean	Total				Mean
	KB*	SB*	KiB*	LTB*		KB*	SB*	KiB*	LTB*	
'Kapangan'	18.27^{bc}	17.83^{b}	20.50^{a}	8.56	16.29^{a}	19.48^{bc}	19.00^{b}	21.05^{a}	10.91	17.61^{ab}
'Tublay'	18.27^{bc}	13.70^{cd}	16.25^{abc}	6.15	13.59^{bc}	19.41^{bc}	15.22^{c}	16.74^{abc}	8.05	14.85^{cd}
'Kibungan'	20.69^{a}	10.90^{e}	14.17^{bc}	8.29	13.51^{bc}	22.98^{a}	12.43^{cd}	14.53^{bc}	11.39	15.34^{cd}
'Wangal'	15.33^{d}	9.37^{e}	13.17^{c}	7.09	11.24^{de}	16.69^{d}	10.77^{d}	13.54^{c}	9.61	12.65^{ef}
'Tuba'	17.03^{cd}	11.40^{de}	14.97^{bc}	6.85	12.56^{cd}	19.01^{bc}	12.70^{cd}	15.38^{bc}	9.11	14.05^{de}
'Mabunga'	19.12^{ab}	16.05^{bc}	13.17^{c}	9.23	14.39^{b}	21.36^{ab}	18.13^{b}	13.49^{c}	11.88	16.22^{cb}
'Itogon'	19.58^{ab}	23.87^{a}	18.17^{ab}	6.97	17.15^{a}	21.05^{ab}	25.68^{a}	18.51^{ab}	9.46	18.68^{a}
'Alno' (ck)	12.46^{e}	10.23^{e}	13.00^{c}	5.62	10.33^{e}	13.84^{e}	11.87^{d}	13.39^{c}	7.26	11.59^{f}
MEAN	17.59^{a}	14.17^{c}	15.42^{b}	7.35^{d}		19.22^{a}	15.73^{b}	15.83^{b}	9.71^{c}	
V x L					**					*
CV (%)	8.10	11.10	16.40	28.0	13.97	6.80	10.30	16.20	27.4	13.88

Means with the same letter are not significantly different at 5% LSD

**Legend: KB= Kapangan, Benguet, SB= Sablan, Benguet, KiB= Kibungan, Benguet, LTB=La Trinidad, Benguet*

'Mabunga' and 'Itogon.' In Sablan, variety 'Itogon' had the heaviest total fresh pod yield. In Kibungan, variety 'Kapangan' recorded the heaviest total fresh pod yield but it was comparable to the total fresh pod yield of varieties 'Itogon', 'Wangal', and 'Mabunga' and in La Trinidad, the total fresh pod yield/plot ranged from 8.05 to 11.88 kg/10m². Across locations, variety 'Itogon' had the highest total fresh pod yield which was comparable to the yield of variety 'Kapangan'. 'Alno,' the check variety, had the lowest total fresh pod yield across locations in Benguet. This indicated that the new improved NSIC- approved or registered varieties had better fresh pod yield than the variety 'Alno' the check variety which is the traditional variety used by the pole snap bean farmers in Benguet. This implies that Benguet pole snap bean farmers have now an idea on new varieties that have better fresh pod yield than their traditional variety.

Among locations, pole snap bean varieties planted in Kapangan had higher total fresh pod yield than in the three locations of more than four kg in Sablan and Kibungan and 10 kgs in La Trinidad. Apparently, varieties with longer flowering periods had higher harvested pods than those varieties that matured earlier (Barbeito et al., 2008).

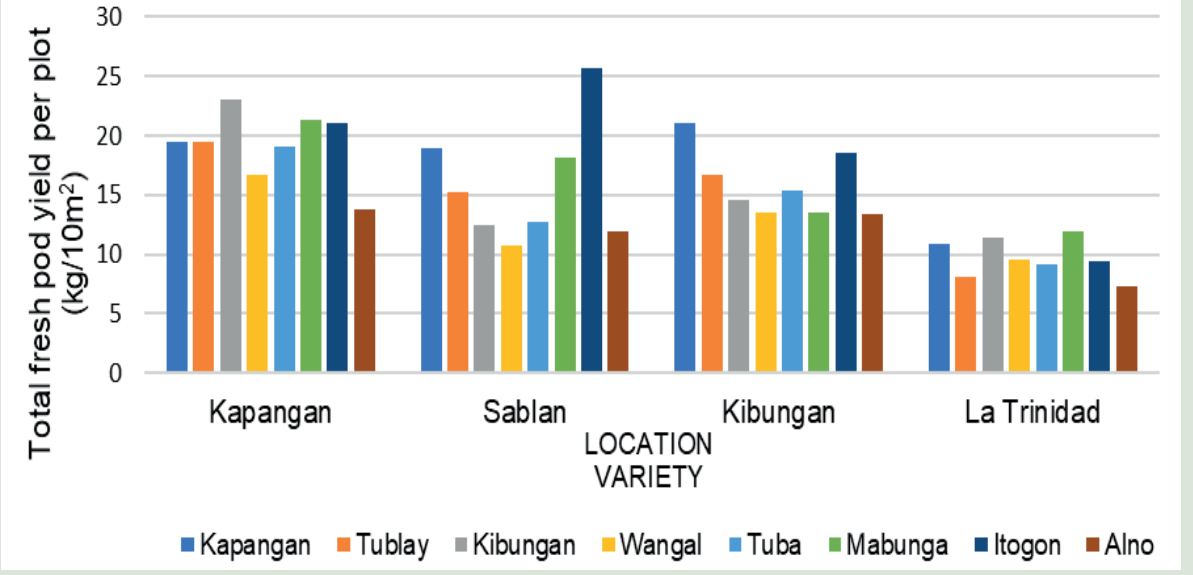
Significant interaction effect of variety and location on total fresh pod yield/plot was observed in pole snap beans tested in four locations (Figure 3). Varieties 'Kibungan,' 'Itogon' and 'Mabunga,' produced the highest total fresh pod yield when grown in Kapangan. In Sablan, variety 'Itogon' was the highest total fresh pod yielder. In Kibungan, grown varieties of 'Kapangan,' and 'Itogon' were the top total fresh pod yielders and in La Trinidad the varieties recorded comparable total fresh pod yield per plot.

Varietal Stability Using AMMI Analysis on Total Fresh Pod Yield

AMMI enables selection of stable and high yielding genotypes in the environment including the adaptability of genotypes according to Mohammadi et al. in 2017. Akter et al. (2014) stated that genotypes near the point of origin are not sensitive to the environmental interactions while genotypes farther from the point of origin are sensitive with significance of interaction to the environment. The AMMI bi-plot 1 in Figure 4 shows that varieties 'Mabunga', 'Kapangan' and 'Itogon' varieties surpassed the grand mean. This implies that these varieties are the top yielders across locations. Interestingly, the Itogon variety recorded the highest total fresh pod yield per plot. Genotypes with higher fresh pod yield than the grand mean are the ideal genotypes according to Yan and Hunt (2001). The AMMI 2 bi-plot in Figure 4 also shows that 'Tublay' was the stable variety that was nearest to the point of origin across locations. 'Itogon' and 'Mabunga' varieties had specific adaptability in Sablan. The 'Kibungan' variety had specific adaptability in Kapangan and La Trinidad. Varieties 'Wangal,' 'Tuba,' 'Alno', 'Tublay', and 'Kapangan' had specific adaptability in Kibungan. Ebdon and Gauch (2002) stated that varieties nearer to the point of origin have stable performance and general adaptability than those with specific adaptability. Furthermore, genotypes or environments with IPCA1 score nearer to zero are least significant and considered as stable genotypes according to Zobel et al. (1988). According to Meng et al. (2016), the genotypes nearer the center, have higher adaptation ability while as it moves away from the center their adaptation ability lowers. AMMI 1 demonstrates the additive effects on the X axis (genotype means and environments) and the first multiplicative interaction axis, the Interaction Principal Component Analysis (IPCA), on the Y axis. Genotypes with scores similar to zero are stable. Genotypes to the right have higher productivity than the general mean of the measured trait. Grouped genotypes show similar adaptation and groups located near to an environment are similarly influenced by that environment. The

Figure 3

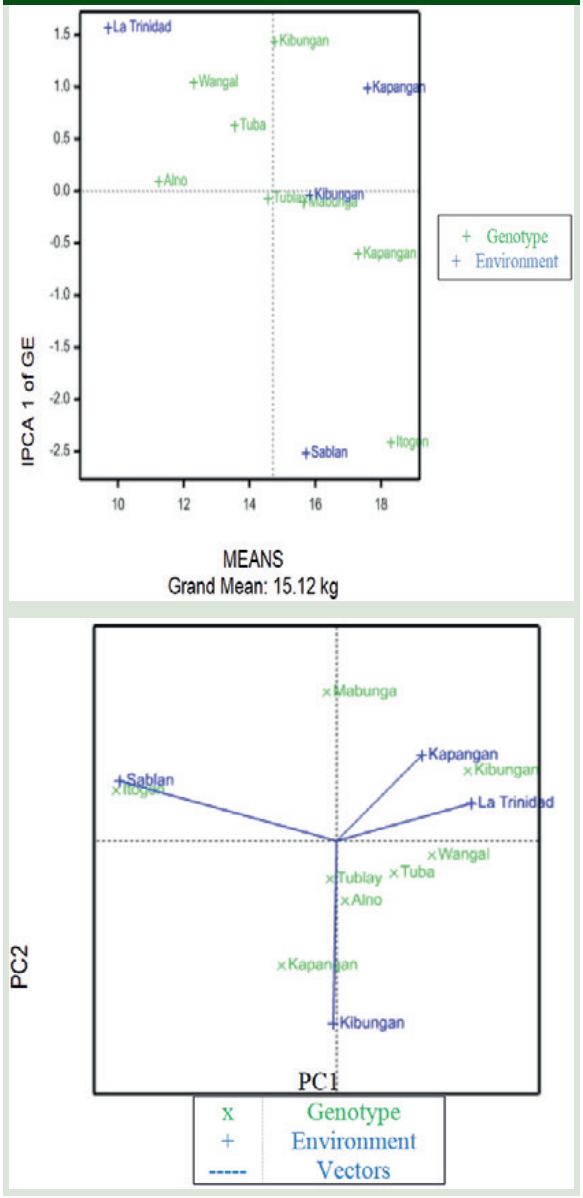
Interaction Effect of Variety and Location on the Total Fresh Pod Yield/Plot (kg/10m²)



second graph, AMMI 2, plots the IPCA1 and IPCA2, genotypes and environments located away from the source contribute to interaction and those with IPCA1 and IPCA2 scores close to zero are stable. When the points occupy the same quadrant in the graph the genotype and environment interact positively and when they are located on opposite quadrants, they interact negatively, Gauch (2006). Specific adaptation can be identified when the genotype shows positive interaction and high productivity in one environment (Funga et al., 2017).

Figure 4

AMMI 1 and AMMI 2 Biplots on the Total Fresh Pod Yield per Plot of Pole Snap Bean Varieties Grown in Four Municipalities of Benguet



Conclusions

The marketable and total fresh pod yield per plot of the eight pole snap bean varieties evaluated significantly differed among each other in four municipalities of Benguet. In Kapangan, Benguet, varieties 'Kibungan,' 'Mabunga,' and 'Itogon' were the top yielders. In Sablan, Benguet, variety 'Itogon' produced the highest fresh pod yield. In Kibungan, Benguet, varieties 'Kapangan,' 'Itogon,' 'Wangal,' and 'Mabunga' recorded the heaviest fresh pod yield and in La Trinidad, the total fresh pod yield/plot of all the varieties tested were comparable. Across locations, varieties 'Itogon,' and 'Kapangan' produced the heaviest marketable fresh pod yield and variety 'Itogon' had the heaviest total fresh pod yield. Pole snap bean varieties grown in Kapangan had the significantly highest marketable and total fresh pod yield/ plot. Significant interaction effect of genotype x environment was observed in all the characters noted in this study. 'Tublay' was the most stable variety in terms of total fresh pod yield which indicates that it had similar performance in all environments. The fresh pod yield of varieties 'Mabunga', 'Kapangan', and 'Itogon' surpassed the grand mean indicating that these varieties are high yielding. Growing pole snap bean in Kapangan, Benguet resulted in high marketable and total fresh pod yield per plot. Variety 'Kibungan' had specific adaptability in Kapangan and La Trinidad. Varieties 'Mabunga' and 'Itogon' had specific adaptability in Sablan and varieties 'Tublay,' 'Tuba, 'Wangal,' 'Alno' and 'Kapangan had specific adaptability in Kibungan.

Recommendations

Based on the results of this study, in Kapangan, Benguet, pole snap bean varieties 'Kibungan', 'Itogon' and 'Mabunga' are recommended for fresh pod production. In Sablan, Benguet, varieties 'Itogon', 'Kapangan' and 'Mabunga' are recommended for fresh pod production. In Kibungan, Benguet, 'Kapangan' and 'Itogon' varieties are recommended for fresh pod production and in La Trinidad, Benguet,

'Mabunga,' 'Kibungan' and 'Kapangan' varieties arerecommended for high fresh pod pole snap bean production. Recommendations are based on good growth and high fresh pod yield, resistance to pest and diseases in each growing municipality. Varieties 'Tublay', 'Mabunga', 'Kapangan', and 'Itogon' are generally recommended for high and stable fresh pod yield production of pole snap bean in Benguet province.

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