High Yielding Indeterminate Bean Varieties to Diversify Bean Farming

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ABSTRACT

Common bean is an important vegetable which provides carbohydrates, proteins, vitamins and minerals for human nutrition, and is often used as a meat alternative in poor countries. Demand for beans for the domestic market in Bhutan is huge which results in increased imports annually. The ban on bean imports citing pesticide residues further led to imbalance in the market (supply-demand) equilibrium. To diversify the choice of cultivars for increased production and to help stabilize market imbalance, two improved cultivars from Japan were evaluated for yield stability, yield potential, length of growing season, pest/disease tolerance, and market and agronomic traits. Grey pole bean was used as a check variety for the study. The variety Prime Green, followed by Brown Pole is preferred over Grey Pole on a range of crop characteristics such as yield potential, disease/pest tolerance, marketable traits (fibrous [stringy] and fleshiness of the pods), and agronomic traits (germination rate, and days to maturity). All three cultivars evaluated show yield stability.

Keywords: *Indeterminate beans; Stable yield; Agronomic traits, Market traits*

1. Introduction

Common bean (*Phaseolus vulgaris* L.) is the second important legume grown for consumption next to Faba bean (*Vicia faba* L.), with 90 % of the area under cultivation (Celmeli et al., 2018). It constitutes more than half the grain legume consumed in the world (Broughton et al., 2003). It is one of the important vegetable crops in world known for its great adaptability and diversity (Vidak et al, 2015 as cited in Tenzin, Lhadon, Phuntsho, & Lhadon, 2018).

Common beans contain carbohydrates, protein, and important vitamins and minerals and are widely used as an alternative protein source to meat, egg and dairy products (Blair et al, 2003 as cited in Tenzin et al., 2018). With the existing poor dietary habits of Bhutanese, wherein carbohydrates rich food, but poor in protein (Tenzin et al., 2018) are predominant, beans are perfect functional food for human nutrition (Câmara, Urrea, & Schlegel, 2013).

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Domestic production of beans doubled in 2018 from 2014 and recorded a concurrent rise in annual import (RSD, 2017) until bean import was banned in 2016 citing the presence of chemical/pesticide residues (DAMC, 2017). In Bhutan, vegetables including beans are cultivated on 29% of the arable land (Katwal, 2013), making it the fifth and sixth most important vegetable crop by cultivation area and production, respectively. The import ban has further aggravated the already imbalanced domestic market equilibrium resulting from land-use conflicts, pests, and human-wildlife conflicts besides others (Katwal, 2013).

Although a diverse range of bean landraces are reported grown widely under different agro-ecological zones in eastern Bhutan (Tenzin et al., 2018), only a few indeterminate genotypes yielded high. Bhutan has only two indeterminate improved varieties registered for cultivation (DoA, 2019) registered, the yields are comparatively lower than indeterminate cultivars (ARDC-Bajo, 2020).

Thus, bean production in Bhutan is limited to a few high yielding cultivars and constrained by land-use conflicts in addition to several other challenges. Therefore, there is a need to diversify improved varieties in the country that would provide higher net returns out of limited resources, and to help alleviate demand gaps through increased production. This study was aimed at evaluating the performance of two indeterminate high yielding bean varieties under Bhutanese conditions.

2. Materials and methods

2.1. Planting material

The varieties were introduced from Japan in collaboration with the Integrated Horticulture Promotion Project (IHPP).

2.2. Location and time Period

The experiment was conducted on-station at ARDC-Bajo under researcher managed experimental trial for two consecutive years (2018-2019). The following year, trials were conducted at three locations at different altitudes in west-central Bhutan under farmers management conditions. (Table 1).

Table 1. Location of the varietal trial.

Location	**Dzongkhag (District)**	**Altitude(*masl*)**
ARDC Bajo (on-station)	Wangdue	1210
Tsendagang	Dagana	650
Rubesa	Wangdue	1350
Limbukha	Punakha	2200

2.3. Experiment Design

Two indeterminate bean varieties viz., Prime Green and Brown Pole were evaluated with Grey Pole as the check variety. The experiment was laid out using a Randomized Complete Block Design (RCBD) with four replications. During the field preparation, 3t/acre compost and 0.5t/acre Suphala (NPK=15:15:15) were applied as basal application. One month after germination, 0.5 t/acre Suphala was top-dressed uniformly (Tomiyasu et al., 2018). Spot sowing of seeds at 25cm between the plants and 30cm between the rows was carried out on 2nd March at ARDC Bajo farm field (on-station). Similarly, beans were grown during their normal growing season at three different places in the farmer's field. Seeds sowing were carried out on 6th march at Tsendagang under Dagana, 15th march at Rubesa under Wangduephodrang Dzongkhags, and on 4th April at Limbukha under Punakha Dzongkhag. On-farm trial plots were subjected to farmer's management practices, except the uniform plant spacing that was followed the same throughout the trial plots.

2.4. Data collection and Data analysis

Bean pods were harvested seven times at horticultural maturity. The bright green, fleshy and tender pods were harvested over a month from 28th April until June last week at ARDC-Bajo (on-station). Similarly, first fruit harvesting commenced from the first week of May at Rubesa and Tsendagang under Wangduephodrang and Dagana dzongkhags, respectively, and from the first week of June at Limukha under Punakha Dzongkhag. Yield data was collected from $7m^2$ treatment plots from both on-station as well as from the on-farm trial plots. Quality attributes such as pod weight, pod diameter, pod length, seed count per pod, number of pods per plant, days to maturity, and the germination rate of different varieties were recorded. Incidences of insect pests and diseases were recorded as percent pod infested, while diseases were recorded on a scale of 1 – 4 (Manandhar et al., 2016).

Preferences for the cultivars by collaborating farmers were studied using a semi-structured questionnaire. Information of yield, disease and pest resistance, market demand, early maturity, pod texture, string and string-less nature of pods were assessed on a scale of 1-5 (where; 1=not good, 2=good, 3=moderate, 4=very good, 5= outstanding). Data were analyzed using Statistical Tool for Agricultural Research (STAR) version 2.0.1and MS Excel 2019. Mean yield, and quality attributes were subjected to one-way ANOVA in STAR 2.0.1.

3. Results and Discussion

3.1. Agronomic traits

Yield potential and stability

Significant yield differences *($P< 0.05$)* were observed among the treatments at on-station as well as on-farm plots (Table 3). No significant differences were observed in the yield of varieties grown

under different locations cultivated in normal growing seasons of the chosen localities (Table 2). There is significant interaction between years and treatments in the yield of the beans.

Table 2. Summary of combined analysis.

SOV	SS	DF	MS	F-cal	F-tab		*p* value
					0.05	0.01	(α=5%)
Years	10400.01	1	10400.01	2.57776	5.99	13.75	
Replication*Years	24207.03	6	4034.51				
Treatment	83312.9475	2	41656.5	22.413**	3.9	6.93	0.000089**
Years*Treatment	11384.1375	2	5692.07	5.59565*	2.85	4.5	0.019193*
E_{pooled}	22303.1	12	1858.59				
Total	151607.225	23					

Table 3. Yield differences among the varieties at ARDC Farm field (on-station).

Variety	**2018 (t/ac)**	**2019 (t/ac)**
Grey Pole (check variety)	4.6 b	4.8 b
Prime Green	7 a	7.3a
Brown Pole	4.5 b	4.7 b
P- value	0.02	0.004
CV%	9.8	13.87

Under all the experimental plots, Prime Green (a.k.a. White Pole) out yielded brown pole and grey pole varieties (Table 3). The yield of the crop is largely attributed to the use of different cultivars, besides other factors such as biotic (pest and disease), abiotic (climatic factors, soil fertility, topography, and water), and the technological factors (Grassbaugh & Bennett, 1998). It was also pointed out that plant attains the highest potential yield under congenial growing conditions (Decoteau, 1998).

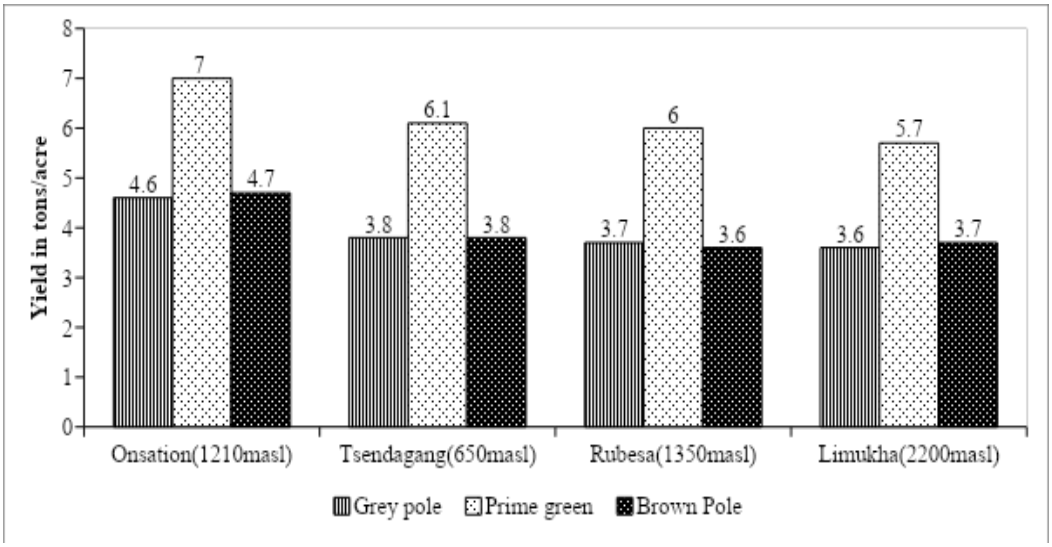

Figure 1. On-station and On-farm Yield comparison.

Yield attributes

The quality attributes of the test varieties such as pod count per plant, weight of the individual pod, pod length and pod diameter were measured (Table 4). Prime Green records highest pod count per plant, and highest pod length than Brown Pole and the check variety. For all these test varieties, pod diameter and seed count per plant almost remained the same.

Table 4. Quality attributes of the test varieties.

Treatment	**Pods/Plant**	**Pod weight (cm)**	**Pod length (cm)**	**Pod diameter (cm)**	**Seeds/Pod**	**Days to Maturity**	**Desirable trait**
Grey Pole	43.5	11.1	14.3 b	1.07	8a	61a	Stringed
Prime green	55	10.9	16 a	1.05	8a	61a	Stringless
Brown Pole	47	12.4	14.4 b	1.25	7b	56b	Mildly stringed
P- value	0.34	0.26	0.017	0.09	0.26	0.0001	
Mean	48.42	11.49	14.8	1.09	7.75	64	
CV (%)	21.5	10.88	3.61	5.06	3.72	0.9	

*****Means with the same letters in a column are not significantly different at 95% confidence level.

Full bloom and days to maturity

The varieties Prime Green and Grey Pole (check variety) took 46 days to reach its full bloom, whereas the variety Brown Pole saw its full bloom at 41 days after sowing. Brown Pole attained horticultural maturity in 50-57 days after sowing, while Prime Green and Grey Pole took 58-64 days. Thus, the variety Brown Pole has the scope to market 7-8 days earlier than Prime Green and Grey Pole. Further, the variety Brown Pole has the potential to market earlier than the already existing varieties like White no. 1by 13-15 days (DoA, 2019). Hence, the variety Brown pole was found as early maturing variety among the three varieties evaluated.

Germination

No significant difference (*P-value < 0.05)* was observed in the germination percentage of test varieties. All the tested varieties showed a germination rate between 90-95 %. The seed germination, however, is solely dependent on the prevalent soil moisture and soil temperature during the seed sowing time. It is observed that seeds germinate at optimum soil moisture, temperature and oxygen (DuPont, 2012). Similar findings were reported where genotypes of *Phaseolus vulgaris* L. exhibited an increased rate of the seed germination from 8-29 °C (White & Montes - R, 1993), and 94% germination rate was recorded at an optimum temperature of 22°C (ARDC-Bajo, 2020; Nleya, Ball, & Vandenberg, 2005). ARDC-Bajo (2020) also recommends beans seeding at an average temperature of 18-27°C at 60-70 % relative humidity.

Major Disease and Pest

Leaf rust incidence was observed less than 5 % on Prime Green and 10-15% on Brown Pole varieties under normal growing conditions. Disease severity of 2 on Prime Green, and 4 on Brown Pole and Grey Pole on a scale of 1-4 was recorded.

Although no major insect pest occurrence was observed, minor incidences of pod borer infestation were observed in all the varieties. No significant difference was observed in insect pest infestation among the varieties. During the two years study period, it was observed that less than 2% of the pods were infested with pod borer. Moderate pod borer incidence of 31 % in common bean (Karel, 1985), 54 % in cowpea and 24-40 % in pigeon pea (Sharma, Saxena, & Bhagwat, 1999) were observed in other countries., However, Dorji, Dorji, and Fujiie (2019) reported 8-10 % of the incidence in the west-central region of the country.

3.2. Market traits

Farmers chose the two tested varieties Prime Green and Brown Pole over check variety Grey pole (Table 5). Characteristics such as soft and fleshy pods, string-less, high market demand, and high yielding favored its assessment over the two.

Although mildly stringed with fleshy and soft pods, variety Brown Pole matures comparatively earlier than already registered bean varieties maturing by 13-15 days (DoA, 2019), and by 7-8 days earlier than other two tested variety.

Table 5. Variety preference rank.

Variety	Ta	HY	MD	Ma	Disease	Pest	Easy cooking	Fleshy	String less	Rank
Grey Pole	3	3	2	3	3	3	3	3	2	**3**
Prime green	4	5	5	4	4	4	5	5	5	**1**
Brown Pole	4	3	3	5	3	4	3	3	3	**2**

*Ta-taste, HY-High yielding, MD-Market demand, Ma- Early maturity, Pest- Pest tolerance, Disease-Disease tolerance.

4. Conclusion

The tested variety Prime Green with its potential to yield 7 t/acre on average out yielded varieties Brown Pole and Grey Pole bean which obtained an average yield of 4.7 and 4.6 tons per acre, respectively. Soft and fleshy pods without fibrous strings are attributed for its high market demand and thus farmers ranked it as their preferred variety followed by the variety Brown Pole. Promotion of these two varieties will increase the productivity as well as varietal diversity of common beans in Bhutan.

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