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Morpho-agronomic characteristics and yield of new promising Soybean (*Glycine max* L.) Lines for Bacnotan, La Union, Philippines

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Abstract

Over the past years, the Philippines has been importing soybeans to meet its domestic requirements. The importation is triggered by the very low production of local soybean farmers. One of the constraints is the low-quality planting materials used by farmers. Hence, the performance of six new soybean lines (IBP Sy 2005-05-179, IBP Sy 2008-04-03A, IBP Sy 2008-05-177A, ICGV 02227, LG Sy 9956, and LG Sy 63) was evaluated. Results revealed that IBP Sy 2008-05-177A had the highest survival rate (57.31%), 100-seed weight (14.75 g), and seed yield per hectare (1.98 t ha-1) with advantages of 11.87%, 4.00g, and 0.41t ha-1 over the check variety, NSIC Sy 9, respectively. However, statistically insignificant differences were noted on plant height, pods per plant, length of pod and seeds per pod, and seed quality. The result showed that IBP Sy 2008-05-177A is a new promising soybean line for farmers in Bacnotan, La Union, Philippines.

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Introduction

Soybean (*Glycine max* (L.) Merr.) is a species of legume native to Eastern Asia, widely grown for its edible bean (Sudarić, 2020). Soybean is economically the most important and nutritious bean in the world (Shea *et al.*, 2020). This is because of its versatility of uses as food (Fehily, 2003), and feed (Ritchie and Roser, 2021), industrial use (Shurtleff and Aoyagi, 2017) and as an effective phytoremediation of polluted agricultural soils (Liestianty and Abdullah, 2014; Mihajlov *et al.,* 2015). It also improves soil properties by adding biologically fixed nitrogen to the soil and boosting beneficial bacterial communities (Liu *et al.,* 2019; Procházka *et al.,* 2019). Soybean seeds typically provide 30–45% protein (moisture-free basis) to as high as 55% protein (moisture-free basis), while most legumes contain only 20–25% protein (Hammond *et al.,* 2003; Hoffman and Falvo, 2004). Soybean also provides a complete and high-quality source of dietary protein that is equal in protein quality to meat, milk, and eggs (Barrett, 2006; Asif and Acharya, 2013). This makes soybeans a good protein source for a vegetarian diet (Rizzo and Baroni, 2018). Soybean seeds are processed into highly digestible and delicious products such as tufo, taho, soymilk, miso, tempeh, natto, oil, and soy sauce. In addition, soybean consumption provides specific phytochemical substances that promote health and are a source of dietary fiber, phospholipids, isoflavones (e.g., genistein and daidzein), phenolic acids, saponins, and phytic acid, while also serving as a trypsin inhibitor. Each of these compounds has been shown to be useful in treating cancer and preventing osteoporosis, as well as in preventing chronic illnesses like arteriosclerosis, heart conditions, diabetes, and senile dementia (Kim *et al.,* 2021).

On the other hand, soybeans are not only a source of nutritious food for humans but also a high-quality vegetable protein in animal feed worldwide (Dei, 2011). Most of the soybeans produced worldwide (77%) are fed to animals for the production of meat and dairy products. More than one-third (37%) of the world's soy is fed to chickens, one-fifth to pigs, and 6% to aquaculture. Only 2% of soy is used in the production of cattle and dairy products. One-fifth of the world's soy is used for human consumption (Ritchie and Roser, 2021). According to USDA Agricultural Projections to 2025, demand for soybean and soybean products is expected to increase significantly during the following ten years (Lee *et al.,* 2016). This is primarily due to population and income growth, which are driving the world's increasing demand for livestock products, as well as the favorable policies implemented by major traders (Lee *et al.,* 2016; Sedibe *et al.,* 2023).

Meanwhile, soybean production in the Philippines is estimated to be around 2,000 to 3,000 tons per year, which is utilized entirely for food. This translates to P120 million to P180 million (BusinessWorld, 2020). Over the past years, the Philippines has been consistently importing soybean and soybean products from other countries to augment the local demand, which amounts to $96.2 milion to $1.25 billion (The Observatory of Economic Complexity, n.d.; Specialty Soya and Grains Alliance, 2020; Philippine Statistics Authority, 2022). The Philippines imports roughly 99% of the soybeans it needs from the United States, with local production accounting for the remaining 1% (Corpuz, 2019; BusinessWorld, 2020; Specialty Soya and Grains Alliance 2020). These imply a viable target market for local soybean farmers. However, poor yields, a lack of high-quality planting materials, and insect pests and disease infestations are pressing issues for local soybean farming (BusinessWorld, 2019). The adverse change in climate observed over the past years is projected to get worse in the coming years (Habib-ur-Rahman *et al.,* 2022). Reports have shown that climate change can reduce crop yields by up to 70% (Boyer, 1982). Maleki *et al.* (2013) mentioned that a 42% reduction in soybean yield is observed when drought is experienced during the grain filling stage. Schlenker and Roberts (2009) found that the threshold temperature for soybeans is 30°C; a rise in temperature to the optimum level boosted soybean output, but after that level, an additional rise in temperature dramatically decreased the yield. To respond to the threatening effects of climate change scenarios, there is a need to look for climate-resilient agricultural practices and adaptation technologies for sustainable productivity (Raza *et al.,* 2019). One of which is the use of climate-resilient crops that could adapt to the present and future environments. Hence, this study was conducted to evaluate the agronomic and yield and yield components of six new promising soybean lines in Raois, Bacnotan, La Union, Philippines.

Material and methods

Experimental location, design, and treatments

The study was conducted at the Techno-demo Farm of Don Mariano Marcos Memeorial State University-North La Union Campus, Raois, Bacnotan, La Union, Philippines, which has GPS coordinates of 16.72646, 120.35358 at an elevation of about 6 m above sea level (Fig. 1) during the dry season. The experimental area was laid out using Randomized Complete Block Design (RCBD), with seven treatments replicated three times. The treatments are the different soybean lines and check variety as follows: Line 1 was IBP Sy 2005-05-179, Line 2 was IBP Sy 2008-04-03A, Line 3 was IBP Sy 2008-05-177A, Line 4 was ICGV 02227, Line 5 was LG Sy 9956, Line 6 was LG Sy 63, and Line 7 was NSIC Sy 9, or the check variety. The seeds were secured from the National Cooperative Test-Field Legumes Technical Working Group (NCT-FLTWG). Other materials were secured locally.

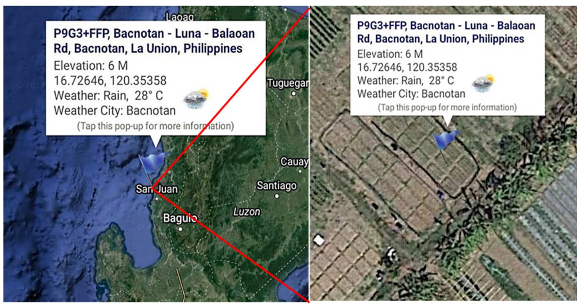

Fig. 1. An image showing the experimental area taken from My Elevation application by RDH Software version 1.72

Land preparation

Each experimental unit had a dimension of 1.5 × 5 m and a total experimental area of 326.25 m². The experimental area was cleared with weeds and foreign materials, then plowed and harrowed thoroughly at a depth of 15 cm using a tractor-drawn implement. Plowing and harrowing were done twice in two-week intervals to granulate the soil and allow the weed seeds to germinate and be controlled easily. Four furrows spaced at 0.5m were made in each experimental unit.

Planting, irrigation, and fertilizer application

The seeds were sown in furrows at two seeds per hill, spaced 10cm between hills, making a total of 50 hills per row. Furrow irrigation was done at planting and twice per week thereafter until 2 weeks before harvesting. The recommended rate of 40-40-60 kg of NPK inorganic fertilizer was applied twice. The first application was at planting, and the last application was 30 days after sowing using complete (14-14-14) and muriate of potash (0-0-60) fertilizers.

Replanting, thinning, and weeding

Replanting the missing hills and thinning was done one week after sowing, leaving one healthy seedling per hill. Proper care and management were employed during the entire growth and development of the plants. Weeds were manually uprooted as soon as weeds appeared to prevent nutrient competition of the plants until the blooming stage to avoid damage to flowers.

Harvesting and postharvest handling

Harvesting was done by manual picking of pods when 75% of the soybean plants had dried up or when the pods turned black or yellowish black. Pods were sundried immediately until brittle to facilitate manual threshing through foot trampling. The threshed seeds were further sundried for three consecutive days to attain a moisture content of 13–14% for a longer shelf life.

Data gathered

The following data were gathered; (1) plant height at maturity (cm), which was taken by measuring 10 samples plants vertically from ground level to the tip of the main stem at maturity using meterstick divided by 10 to get the average; (2) survival rate (%), of which the number of survived plants per plot at harvesting was counted divided by the 150 (plants per plot after thinning) multiplied by 100; (3) number of pods per plant, was determined by counting the number of developed pods from 10 of the sample plants per plot, divided by 10; (4) length of the pod (cm), was taken by measuring the base to the tip of the 10 randomly selected pods from the 10 sample plants in centimeters using foot ruler, divided by 10; (5) number of seeds per pod, was obtained by counting the number of seeds of 10 randomly selected mature pods from 10 sample plants per plot, divided by 10 to get the average; (6) weight of 100 seeds (g), was taken by weighing 100 randomly selected seeds from each plot in grams; (7) seed yield per hectare (kg), this was taken by extrapolating the seed yield per plot (g) into seed yield per hectare (kg) using the formula: Yield in kg per hectare = (Yield per plot (kg) x Area/hectare)/Area per plot, and (8) seed quality following the Guidelines in conducting National Cooperative Test for Field Legumes by the National Cooperative Test for Field Legumes Technical Working Group (NCT-FLTWG) of the Philippines.

Data analysis

The data gathered were subjected to Analysis of Variance (ANOVA) in Randomized Complete Block Design (RCBD) with 3 blocks. The significant difference between means was further tested using Tukey's Honest Significant Difference (HSD) Test at 5% and 1% levels of significance. The IRRI-STAR application was used to analyze the data.

Results and discussion

Yield components, growth parameter and survival rate

The soybean lines tested revealed insignificant differences in terms of pods per plant, length of pods, seeds per pod, and plant height at maturity, with means ranging from 36.40 to 38.95, 3.81 to 4.57 cm, 2.27 to 2.60 cm, and 52.60 to 56.53 cm, respectively, while a significant difference was revealed in terms of survival rate (Table 1).

Line 3-IBP Sy 2008-05-177A gave the highest survival rate of 57.31%, while Line 6-LG Sy 63 gave the lowest survival rate of 36.38%. However, a comparison of means revealed that all six new soybean lines were insignificant compared to the check variety, NSIC Sy 9, with a survival rate of 45.44%.

Weight of 100 seeds, seed yield and seed quality

The weight of 100 seeds per soybean line (g), seed yield (t ha-1), and seed quality of the different soybean lines tested in Raois, Bacnotan, La Union, Philippines are presented in Table 2. Soybean lines revealed highly significant differences in the weight of 100 seeds, while significant differences were revealed in terms of seed yield ha-1. The heaviest weight of 100 seeds was noted in Line 2-IBP Sy 2008-04-03A with 14.75 g, while Line 5-LG Sy 9956 produced the lightest with 10.25 g. As to the comparison of means, Line 2-IBP Sy 2008-04-03A, which produced the heaviest 100-seed weight, was found to be statistically similar to all the lines except for Line 5-LG Sy 9956 and the check variety, NSIC Sy 9, which are statistically similar.

As to seed yield, Line 2-IBP Sy 2008-04-03A produced the highest with 1.98 t ha-1 while Line 6-LG Sy 63 produced the lowest with 1.12 t ha-1. A comparison of means disclosed that all new soybean lines tested were found to be comparable with the check variety, NSIC Sy 9, with 1.57 t ha-1. However, it was noted that Line 2-IBP Sy 2008-04-03A had a 0.41t ha-1 seed yield advantage over the check variety, NSIC Sy 9. The result showed that IBP Sy 2008-05-177A (1.98 t ha-1) outyielded registered Philippine soybean varieties such as NSIC 2018 Sy 11 or La Carlota Sy 4, NSIC 2019 Sy 12 or Tiwala 14, NSIC 2019 Sy 13 or Tiwala 16, NSIC 2019 Sy 14 or Tiwala 18, and NSIC 2019 Sy 15 or Tiwala 20 with average dry season yields of 1.83 t ha-1, 1.97 t ha-1, 1.78 t ha-1, 1.86 t ha-1, and 1.78 t ha-1, respectively (National Seed Industry Council, 2020). However, the yield is still below the global average yield per hectare, which is 2.85 t ha-1 (Filipenco 2023) or the top producing countries, such as the USA, Brazil, Paraguay, and Argentina, with average yields of 3.45 t ha-1, 3.44 t ha-1, 2.89 t ha-1, and 2.81 t ha-1, respectively (Our World In Data, 2023).

Table 1. Pods per plant, length of pod (cm), seeds per pod, plant height (cm) at maturity, and survival rate (%) of the different soybean lines tested in Raois, Bacnotan, La Union, Philippines

Soybean Lines	Pods per plant	Length of pod	Seeds per pod	Plant height	Survival rate
L1-IBP Sy 2005-05-179	38.95	3.88	2.48	53.13	44.31[ab]
L2-IBP Sy 2008-04-03A	37.28	4.57	2.27	52.60	43.12[ab]
L3-IBP Sy 2008-05-177A	37.50	3.81	2.50	56.10	57.31[a]
L4-ICGV 02227	38.88	4.14	2.50	53.48	46.31[ab]
L5-LG Sy 9956	37.58	4.08	2.60	56.53	50.94[ab]
L6-LG Sy 63	36.40	3.86	2.50	54.40	36.38[b]
L7-NSIC Sy 9 (check variety)	39.05	4.29	2.67	59.28	45.44[ab]
F-test	0.99	0.39	0.46	0.93	0.03
C.V. (%)	1.63	8.00	9.97	16.05	16.19

All means with the same letter are not significantly different at 0.05 level (HSD).

Table 2. Weight of 100 seeds (g), seed yield (t ha-¹), and seed quality of the different soybean lines tested in Raois, Bacnotan, La Union, Philippines

Soybean Lines	Weight of 100-seeds*	Seed Yield**	Seed Quality
L1-IBP Sy 2005-05-179	10.75[a]	1.23[ab]	1.00
L2-IBP Sy 2008-04-03A	12.75[ab]	1.63[ab]	1.00
L3-IBP Sy 2008-05-177A	14.75[a]	1.98[a]	1.00
L4-ICGV 02227	11.25[ab]	1.25[ab]	1.00
L5-LG Sy 9956	10.25[b]	1.45[ab]	1.00
L6-LG Sy 63	11.50[ab]	1.12[b]	1.00
L7-NSIC Sy 9 (check variety)	10.75[b]	1.57[ab]	1.00
F-test	0.01	0.04	-
C.V. (%)	13.74	24.77	-

*All means with the same letter are not significantly different at 0.01 level (HSD). **All means with the same letter are not significantly different at 0.05 level (HSD).

All the new soybean lines produced "good" seeds, or seeds with 0–20% shriveled and crack with discolored seeds comparable with the check variety, NSIC Sy 9.

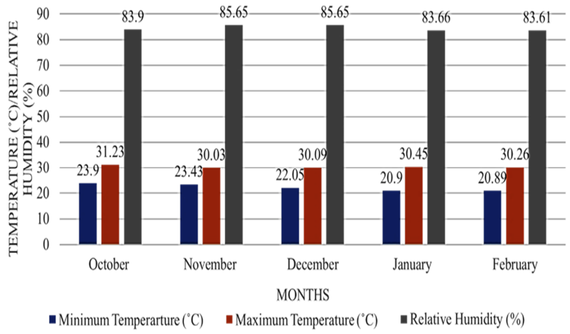

Fig. 2. Agro-meteorological data (temperature and relative humidity) during the conduct of the study

Agro-meteorological data

The average monthly minimum and maximum temperature (°C), relative humidity (%), and rainfall (mm) were recorded during the study (Fig. 2). The temperature during the study ranges from 20.89°C to 31.23°C. The highest minimum and maximum temperatures were recorded in October at 23.90°C and 31.23°C, while the lowest minimum and maximum temperatures were recorded in February and November at 20.89°C and 30.03°C, respectively. The relative humidity during the study ranges from 83.61% to 85.65%. The highest relative humidity was recorded in November and December with a similar average of 85.65%, while the lowest was recorded in February with 83.61%. As to the rainfall reading, the highest rainfall was recorded in November with 208 mm, followed by October with 15.20mm and December with 3.80mm. There was no rainfall in January and February. The total rainfall accumulated was 227mm. Accorrding to Nimje (2017) and de Avila *et al.* (2013), the optimum temperature for soybean production is 20-30°C. The agro-meteorological data were collected from DMMMSU-PAGASA Agro-met Station at Don Mariano Marcos Memorial State University- North La Union Campus (DMMMSU-NLUC), Sapilang, Bacnotan, La Union, Philippines.

Conclusion

Based on the results of the study, it is concluded that IBP Sy 2008-05-177A had the highest survival rate, 100-seed weight, and seed yield per hectare with advantages of 11.87%, 4.00g, and 0.41t ha-1 over the check variety, NSIC Sy 9, respectively. All soybean lines are comparable in terms of pods per plant, length of pod, seeds per pod, plant height, and seed quality.

Recommendations

Based on the results, IBP Sy 2008-05-177A is a promising soybean line for farmers in Bacnotan, La Union, Philippines. Further, the adoption of suitable technologies or the conduct of studies to improve the performance of soybean plants, particularly in terms of survival percentage, is also recommended.

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