Performance of soybean Grobogan-derived lines under citrus trees shade

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Abstract. Developing soybeans through utilizing land between plantation crops, industrial forest plantations, and horticulture crops (including citrus plants) in agroforestry, agri-horticulture, agro-pastoral, and agro-silvopastoral systems need to be supported by the availability of adaptive varieties to the respective environment. For the reason, research aimed to evaluate the response of Grobogan-derived promising lines planted under the shade of citrus trees were carried out in the first dry season 2018. Citrus trees used in the study was 1.5 to 2.0 years old, located in Sembulung Village, Cluring District (L1) and Kradenan Village, Purwoarjo District (L2) Banyuwangi Regency. Ten promising lines derived from Grobogan variety along with Grobogan as the check variety were used in the study. In each location, the genotypes were arranged in a randomized complete block design with four replications. Each genotype was planted in a 12 m² plot size, 40 cm x 15 cm planting space, 2 plants per hill. Results showed various genotypes responses to the environments as indicated by significant G x E interactions observed on yield and yield components. Average yield in L2 was 3.25 t ha⁻¹ and higher than that in L1 (2.86 t ha⁻¹). GROB/IAC-453-7 line was consistently produced high yield in the two locations, i.e., 3.40 and 3.58 t ha⁻¹ in L1 and L2, respectively; while GROB/PANDER-428-I had a significantly larger seed size as indicated by it 100-seeds-weight 24.94 g (L1) and 26.51 g (L2), compared to that of Grobogan, i.e., 20.35 g (L1) and 24.61 g (L2).

1. Introduction
In line with the population growth, the need for food supply continues to increase, both in quantity and quality, including soybean consumption. The demand for soybean also increases from year to year. At present national soybean production cannot fulfill these needs, which causes imported soybeans to increase.

Efforts to increase national soybean production face problems, including conversion of productive agricultural land to housing and industry use, expansion of planting areas was very slow due to land-use competition among food crops, especially with rice and maize. Soybean plants do not have special area, so the opportunity for development is by utilizing area between plantation crops, industrial forest plantations, and horticulture crops (including citrus plants) in agroforestry, agri-horticulture, agro-pastoral and agro-silvopastoral systems, which are assessed more effective in improving soil organic matter content [1]. Data on Agriculture Statistics in 2017 shows that in 2016 the national citrus plant area was 60,000 ha [2]. Citrus are planted in a wide spacing, which is 5 m x 4 m. About 60 to 70% of the wide spacing between citrus trees can be exploited to plant intercrops, which can improve the
efficiency of land use, farmers' income, food security, reduce soil erosion, pests, diseases and weed control [3, 4 and 5]. The space between citrus trees can be used for annual crop cultivation. There are several advantages for planting seasonal crops as intercrops, which in addition to those above-mentioned benefits, intercrops can also preserve soil moisture and organic matter, as well as protecting the soil from washing up nutrients [6]. But this practice is not always considered ideal in all fruit crops, because of the possibility of competition between the main crops (fruit trees) and intercrops. Intercropping must have synergistic or complementary effects on the main crop [7]. Therefore, the agronomic characteristics of the plants used in the intercropping system are very important. Plant components that have different harvest times must be chosen to reduce competition for the same resources at the same time. Besides, the characteristics of roots and plant parts above the ground of plants used in the intercropping system are suggested to be different for effective utilization of moisture and sunlight.

The success of the intercropping system can be achieved by several agronomic manipulations, such as arranging plant density, planting time, resource availability and intercropping patterns [3]. Intercropping can significantly increase total productivity compared to monocropping, due to better and more efficient use of water, nutrition, and light energy [8, 9, and 10].

Intercropping between citrus and legumes crops (soybean and beans), significantly increased citrus yield compared to citrus monoculture, i.e. 72.2 kg tree-1 in intercropping and 68.5 kg tree-1 in monoculture. The intercropping can maintain much higher leaf nutrition levels (2.35% N, P 0.13%, 2.08% K, Fe 86.5 ppm, Mn 71.1 ppm, Cu 22, 2 ppm, and 22.0 ppm Zn) compared to citrus monoculture (2.29% N, 0.13% P, 2.47% K, 79.2 ppm Fe, 63.8 ppm Mn, 21.7 ppm Cu, and 23.2 ppm Zn) [11]. Intercropping of citrus with peanut, mungbean or soybean has a better effect on the citrus growth, compared to the intercropping with corn which suppresses the growth of citrus [12]. Legumes crops as intercrops have a better function in improving soil fertility compared to wheat and corn plants [3]. The highest yield of Nagpur mandarin orange of 20.0 tons/ha (72.3 kg tree-1) was achieved by intercropping soybeans with the orange crops [13]. In another study [14], reported that intercropping between oranges and soybeans causes a reduction in soybean yield between 54.88 to 70.85%. The high yield loss was due to sunlight competition, where soybean with lower plant posture than citrus experienced shading by the citrus canopy which caused a reduction in sunlight received by the soybean. That yield losses can be reduced by planting soybean varieties that are adaptive to intercropping environmental conditions.

Improved cultivars adapted to shade environments have been released in 2016. Those cultivars, Dena 1 and Dena 2, belong to medium maturity and medium seed size. Demand for large seed size is increasing as most of the soybean consumption is used as tempeh raw material. Large seed size increases tempeh rendemen and improves tempeh performance. Citrus plantations mostly planted in dry areas with limited water resource, therefore soybean short maturity would be a better option cultivar to be developed as intercrop in the plantation. Improvement for large seed size and early maturity while retained shade tolerance characteristics in Dena 1 would be beneficial in disseminating the new improved variety and increase soybean productivity in intercropping system. Grobogan was used as gene source parental for those characters improvement, it was crossed with three shade tolerance genotypes and 10 promising lines have been obtained from those crosses. This research aimed to determine the response of those promising Grobogan-derived lines planted under the shade of citrus trees.

2. Materials and Methods

Ten soybean promising lines and one check variety (Grobogan variety) were evaluated among citrus trees of 1.5 to 2.0 years age, in Sembulung Village, Cluring District (L1) and Kradenan Village, Purwoarjo District (L2) Banyuwangi Regency, in the first dry season 2018. Those ten lines were derived from Grobogan, an improved variety, which was crossed with three shade tolerance genotypes, i.e. IT (6 lines), Panderman (3 lines), and IAC 100 (1 line). At each location, the lines were
arranged in a randomized complete block design replicated four times. Each genotype was planted in a 12 m² plot size. Grobogan was used as a check variety in each location.

Land preparation included land clearing from previous crop residues followed by tillage practice. Planting was done at a spacing of 40 cm x 15 cm, 2-3 seeds hill⁻¹. Before planting, the seeds were treated with Karbosulfan insecticide as seed treatment. Soybean plants were thinned at 10 days after planting (dap) to leave 2 plants hill⁻¹. To prevent excessive weed growth, at 1-2 weeks before planting (wbp) the soil was sprayed using herbicides (Parakuat Diklorida 276 g/l), with a concentration of 2 ml L⁻¹ water and weeding was done at 2-4 weeks after planting. Pest and disease controlled by spraying active ingredients pesticides: emamektin benzoate 5.7%, profenofos 500 g/l, karbosulfan 5%, deltametrin 25 g/l, and fungicides (mankozep 80%, kaptan 50). A spray volume of 400 L ha⁻¹ during the vegetative phase and 500 L ha⁻¹ in the generative phase. Fertilization was done at 7 days after planting (DAP) using 150 kg Phonska and 100 kg SP36 ha⁻¹. The plants were irrigated at planting, fertilizer application, pod formation, and pod filling pod.

Observations included plant height, number of branches, number of nodes, number of filled pods and seed weight plant⁻¹ measured on 5 sample plants, while observations of the weight of 100 seeds and seed yield were plot-based at harvest time. Meanwhile, observation of light intensity was carried out at 12.00 with intervals of 2 weeks. Observations were made in two positions, namely under the citrus canopy or above the soybean canopy and above the citrus canopy, using a Lux meter. Shade intensity is calculated by the formula = (1 - (light intensity under citrus canopy divided by light intensity above citrus canopy)) x 100%.

The data collected were statistically analyzed using the combined analysis of variance. The treatment means were separated using the Least Significance Difference (LSD) at 5% level of probability. To find out the degree of relationship between characters, was done correlation analysis

3. Results and Discussion

Citrus trees caused shade stress on soybean, as indicated by light intensity difference between under- and above-citrus canopy (Figure 1). Shade intensity under the citrus in L1 ranged from 60 to 70%, whereas in L2 were ranged between 49 to 67%. Those shade intensity levels showed that soybean plants in L1 experienced heavier stress compared to those in L2 environment, and those would affect soybean growth and yield.

![Figure 1. Light intensity above and under citrus canopy in L1 (Sembulung Village) and L2 (Kradenan Village).](image-url)
12.66%, and 21.17%, respectively, higher than those in L1. Plant height of Grobogan, the check variety, were the highest among the genotypes tested, both in L1 and L2, but not necessarily with the nodes and filled pods number. This was due to higher the number of nodes in Grobogan variety than the other genotypes. Correlation analysis in Table 4 showed that plant height was positively correlated significantly with the number of nodes \( r = 0.69^{**} \), indicated an increase in plant height was strongly associated with an increase in the number of nodes. Based on a comparison between plant height and the number of nodes, Grob/Pander-428-1 line has the longest internode in L1 (4.67 cm node\(^{-1}\)) and the shortest in L2 (2.81 cm node\(^{-1}\)). Shade level stress at L1 is more severe than in L2. This shows that the Grob/Pander-428-1 line was etiolated with an elongation rate of 1.86 cm node\(^{-1}\). Etiolation is one indicator of plant sensitivity response to shading stress.

**Table 1.** Combined variance analysis of yield and yield components of soybean genotypes evaluated in two environments.

| Characters                   | Genotypes (G) | Environments (E) | G x E |
|-----------------------------|---------------|------------------|-------|
| Plant height                | 138.061**     | 376.409**        | 54.834** |
| Number of branches plant\(^{-1}\) | 0.595\(^{ns}\) | 0.409\(^{ns}\)  | 0.859\(^{ns}\) |
| Number of nodes plant\(^{-1}\) | 26.277**      | 82.102**         | 18.927** |
| Number of filled pods plant\(^{-1}\) | 560.232**     | 2210.011**      | 125.636** |
| Seed weight plant\(^{-1}\)  | 122.025**     | 1245.839**       | 31.790** |
| Seed yield ha\(^{-1}\)      | 0.485**       | 3.338**          | 0.141** |
| Weight of 100 seeds         | 41.654**      | 41.980**         | 4.658** |

Note: * and ** = significantly different at \( \alpha 5 \) and \( 1\% \), ns = not significantly difference at \( \alpha 5\% \).

**Table 2.** Average of plant height, number of branches, number of nodes, and number of filled pods per plant of soybean genotypes in L1 (Sembulung Village) and L2 (Kradenan Village).

| Genotypes              | Plant height (cm) | Number plant\(^{-1}\): Branches | Nodes | Filled pods |
|------------------------|-------------------|----------------------------------|-------|-------------|
|                        | L1    | L2    | L1 | L2 | L1 | L2 | L1 | L2 |
| GROB/IT-7-1            | 60    | 64    | 3  | 2  | 19 | 17 | 66 | 68 |
| GROB/IT-7-2            | 52    | 52    | 2  | 2  | 14 | 14 | 41 | 45 |
| GROB/IT-7-3            | 50    | 55    | 3  | 2  | 16 | 15 | 48 | 51 |
| GROB/IT-7-5            | 52    | 53    | 3  | 2  | 15 | 13 | 43 | 47 |
| GROB/IT-7-7            | 51    | 67    | 3  | 3  | 16 | 21 | 54 | 81 |
| GROB/IT-17-1           | 55    | 57    | 3  | 3  | 15 | 16 | 49 | 61 |
| GROB/PANDER-395-2      | 52    | 61    | 2  | 3  | 15 | 19 | 42 | 61 |
| GROB/PANDER-397-6      | 58    | 54    | 2  | 3  | 15 | 19 | 42 | 56 |
| GROB/PANDER-428-1      | 56    | 55    | 2  | 3  | 12 | 20 | 38 | 51 |
| GROB/IAC-453-7         | 53    | 59    | 3  | 2  | 15 | 16 | 48 | 50 |
| Grobogan               | 62    | 69    | 3  | 3  | 18 | 22 | 51 | 59 |
| **Average**            | 54.57  | 58.70  | 2.48 | 2.63 | 15.25 | 17.18 | 47.32 | 57.34 |
| **LSD 5%**             | 1.74   | ns     | 2.33 | 8.87 |

Note: numbers in one column followed by the same letters show no significant difference at \( \alpha 5\% \), ns = not significant difference at \( \alpha 5\% \), GROB = Grobogan, PANDER = Panderman, IT = IAC 100/Tanggamus.

The highest filled pods and nodes number in L1 were found on the same line, i.e. Grob/IT-7-1. The line’s filled pods number was higher compared to that of Grobogan, the check variety, both in L1 and
L2. The line’s filled pods numbers were 29.41% and 15.25% higher compared to filled pods number obtained by Grobogan variety in L1 and L2. The highest number of filled pods in L2 was obtained by Grob/IT-7-7 with 81 filled pods plants⁻¹, and it was 37.29% higher than that of Grobogan variety. Grob/IT-7-1 and Grob/IT-7-7 lines were derived from hybridization between Grobogan variety and elite line IT, stands for IAC 100/Tanggamus, a shade-tolerant line.

The number of filled pods was positively correlated significantly with seed weight plant⁻¹ (r=0.89**) and seed weight plant⁻¹ was positively correlated significantly with seed yield ha⁻¹ (r=0.58**) (Table 4). Contribution of seed weight plant⁻¹ to seed yield ha⁻¹ was higher than the contribution of the other yield component characters.

In general, soybean performed better growth and development in the L2 environment compared to the L1 environment. This was due to higher shade stress in L1 than L2 environment. Light directly affects the growth and potential yield of plants [5]. The opportunity for soybean plants to absorb sunlight is less than the main crop, because the soybean posture is shorter than the main crop. In intercropping systems, the shade of the main crop greatly affects the growth and development of soybeans and causes changes in the light intensity and spectrum.

Table 3. Seed weight per plant, seed yield per hectare and 100-seeds weight of soybean genotype in L1 (Sembulung Village) and L2 (Kradenan Village).

| Genotypes           | Seed weight (g plant⁻¹) | Seed yield (t ha⁻¹) | Weight of 100 seeds (g) |
|---------------------|------------------------|---------------------|------------------------|
|                     | L1         | L2         | L1         | L2         | L1         | L2         |
| GROB/IT-7-1         | 26.41      | 36.94      | 2.87       | 3.50       | 17.54      | 19.95      |
| GROB/IT-7-2         | 17.52      | 20.94      | 2.62       | 3.35       | 20.91      | 20.65      |
| GROB/IT-7-3         | 21.67      | 23.41      | 2.82       | 2.92       | 20.92      | 23.03      |
| GROB/IT-7-5         | 18.54      | 22.48      | 3.00       | 3.48       | 20.35      | 22.88      |
| GROB/IT-7-7         | 22.71      | 36.02      | 2.98       | 3.21       | 20.05      | 20.11      |
| GROB/IT-17-1        | 18.29      | 24.70      | 2.78       | 2.93       | 20.66      | 21.49      |
| GROB/PANDER-395-2   | 21.16      | 31.91      | 2.83       | 3.31       | 25.21      | 25.83      |
| GROB/PANDER-397-6   | 18.85      | 28.96      | 2.77       | 3.17       | 24.02      | 26.19      |
| GROB/PANDER-428-1   | 15.00      | 26.04      | 2.16       | 3.00       | 24.94      | 26.51      |
| GROB/IAC-453-7      | 21.35      | 24.25      | 3.40       | 3.58       | 22.53      | 21.44      |
| Grobogan            | 20.91      | 29.54      | 3.24       | 3.32       | 20.35      | 24.61      |
| Average             | 20.22      | 27.74      | 2.86       | 3.25       | 21.59      | 22.97      |
| LSD 5%              | 5.91       | 0.13       | 1.64       |

Note: numbers in one column followed by the same letters show no significant difference at a 5%, ns = not significant difference at a 5%, GROB = Grobogan, PANDER = Panderman, IT = IAC 100/Tanggamus

Seed weight plant⁻¹, seed yield ha⁻¹, and weight of 100 seeds of each genotype differed between the two locations. The highest seed weight plant⁻¹ in L1 (26.41 g plant⁻¹) and L2 (36.49 g plant⁻¹) reached by GROB/IT-7-1, and there was another line, i.e. GROB/IT-7-7 which produced the same seed weight plant⁻¹ (36.02 g plant⁻¹) in L2. Seed weight plant⁻¹ of those two lines were higher than the seed weight of Grobogan, the check variety as well as their maternal parents. The seed weight plant⁻¹ of GROB/IT-7-1 in L1 and L2 were 26.30% and 25.05% higher than seed weight plant⁻¹ of Grobogan variety, and that in GROB/IT-7-7 evaluated in L2 was 21.94% higher. However, the highest seed yields in L1 and L2 was achieved by another line, i.e. GROB/IAC-453-7 with 3.40 and 3.58 t ha⁻¹ seed yield. The yields were 4.94 and 7.83% higher than that achieved by Grobogan, the check variety. In addition to GROB/IAC-453-7, there were two lines produced significantly higher seed yield than Grobogan in L2, namely GROB/IT-7-1 (3.50 t ha⁻¹) and GROB/IT-7-5 (3.48 t ha⁻¹).
Table 4. Correlation between seed yield and yield component characters of soybeans intercropped with citrus in L1 (Sembulung Village) and L2 (Kradenan Village)

|     | PH  | NB   | NN   | NFP  | SWP  | SY   | W100S |
|-----|-----|------|------|------|------|------|-------|
| PH  | 1.00|      |      |      |      |      |       |
| NB  | 0.35*| 1.00|      |      |      |      |       |
| NN  | 0.69**| 0.75**| 1.00|      |      |      |       |
| NFP | 0.71**| 0.65**| 0.77**| 1.00|      |      |       |
| SWP | 0.68**| 0.48*| 0.77**| 0.89**| 1.00|      |       |
| SY  | 0.35in| 0.25in| 0.36in| 0.42*| 0.58**| 1.00|       |
| W100S | -0.04in| -0.21in| 0.08in| -0.28in| 0.01in| -0.09in| 1.00  |

Note: PH: plant height, NB, NN, and NFP are number of: branch, node, fill pod respectively, SWP: seed weight plant\(^{-1}\), SY: seed yield, and BBJ: weight 100 seeds

In general, the average seed yield of the tested lines including the check variety in L2 was higher compared to that obtained in L1. This was due to the shade stress intensity by the main crop canopy (citrus) in L1 higher than in L2. Higher shade stress intensity decreases the amount of sunlight received by soybean leaves, where light is the main energy source in photosynthesis. Sunlight is the main factor affecting plant growth and development; through photosynthesis, plants use sunlight to convert water and carbon dioxide into sugar, and photosynthetic pigments play an important role in the process of converting light energy into chemical energy. Thus, the reduction in light energy received by soybean leaves results in disrupted photosynthesis, which results in a yield decrease. Photosynthesis in leaves is the basic material used for seed formation [16].

Seed size expressed as weight of 100-seeds ranged from 17.5-25.2 g in L1 and 19.9-26.5 g seeds in L2. Following soybean seed size classifications, all of the lines belong to large seed size. Most of the tested lines had the same seed size to Grobogan, three lines were larger, and only one line was smaller compared to Grobogan (Table 3). In L1, line with smaller seed size than Grobogan variety was GROB/IT-7-1, and there were five lines with seed size equivalent to the Grobogan variety, i.e. GROB/IT-7-2, GROB/IT-7-3, GROB/IT-7-5, GROB/IT-7-7, and GROB/IT-17-1, and four lines with larger seed size, i.e. GROB/PANDER-395-2, GROB/PANDER-3957-6, GROB/PANDER-428-1, and GROB/IAC-453-7. While in L2, there were six lines with seed size smaller than Grobogan, i.e. GROB/IT-7-1, GROB/IT-7-2, GROB/IT-7-5, GROB/IT-7-7, GROB/IT-17-1, and GROB/IAC-453-7, three lines with equivalent seed size to Grobogan, i.e. GROB/IT-7-3, GROB/PANDER-395-2, and GROB/PANDER-397-6 and one line, i.e. GROB/PANDER-428-1 with a larger seed size compared to Grobogan seed size (20.35 g 100 seeds\(^{-1}\)).

Average seed size of the tested lines in L1 (21.59 g 100 seeds\(^{-1}\)) was smaller than that in L2 (22.97 g 100 seeds\(^{-1}\)). Although the maximum soybean seed size is determined by genetic potential, but the seed size can be modified by environmental conditions [17]. Variation in soybean seed size is different, due to changes in environment during the reproductive period. Small seed size cultivars have the greatest stability in maintaining seed size, followed by medium seed size cultivars, and large seed size cultivars are the most unstable.

4. Conclusions

Response of soybean Grobogan-derived lines under citrus trees shades was different between locations, as indicated by the presence of genotypes and environments interactions on yield and all yield components (plant height, number of nodes, number of filled pods, seed weight per plant, seed yield per hectare, and seed size) except number of branches. Nevertheless, one line, i.e. GROB/IAC-453-7, was able to give highest seed yields, both in the two environments which representing different shade intensities, and a line, namely GROB/PANDER-428-1, that had a significantly larger seed size than Grobogan seeds. Lines derived from Grobogan variety have the opportunity to give better
response to the shade of citrus trees, higher yield and yield components compared to the parental variety (Grobogan).

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