Effects of relay-planting several peanut rows on yield of two maize varieties at different row spacing

W Wangiyana, I K Ngawit and N Farida

Faculty of Agriculture, University of Mataram; Jln. Majapahit No. 62, Mataram, Lombok, Indonesia
*Email: w.wangiana@unram.ac.id

Abstract. Intercropping maize with peanut has been reported to change the availability of some nutrients in the rhizosphere of the intercrops which resulted in different concentration of some nutrients in the above-ground parts of the intercrops compared with its monocrop. This study aimed to examine the effects of relay-planting several rows of peanut between rows of maize at different spacing on yield components of two maize varieties, by conducting an SSP-designed experiment testing three treatment factors, namely additive intercropping (I) maize with peanut as the main plots, maize varieties (V) and maize row spacing (S). The results indicated that variety differences had the most significant effects on the observation variables, followed by row spacing, and intercropping, but there were three-way and two-way interaction effects on green leaf number at 9 weeks old, showing that the highest green leaf number was on hybrid maize plants of 75 cm row spacing intercropped with three rows of peanut. On grain yield per plant, there was no significant effect of row spacing, but grain yield per m² was highest under the lowest (60 cm) row spacing and intercropping with three rows of peanut, i.e. 673.34 g/m² on waxy maize (463.7 g/m² in monocrop), and 736.04 g/m² on hybrid maize (656.3 g/m² in monocrop), which indicates the possibilities to reduce row spacing under additive intercropping with peanut.

1. Introduction
Maize (Zea mays L.) is a versatile plant, because all the above-ground parts of the plant can be used either as food, animal feed or industrial raw materials, and even the wastes, such as dry cobs, can be used as fuels [1]. For use as a food ingredient, maize in general contains a lot of nutrients and crude fibre needed by the human body. Whole maize grain contains 8-11.5% protein, 68-74% starch, and 4.0-5.5% fat [2]. In Indonesia, in terms of the total annual harvested areas published in the website of the Central Bureau of Statistics (https://bps.go.id), maize is the second staple food crops after rice, which is mostly consumed in the form of processed or semi-finished products. Based on the results of study conducted by the Central Bureau of Statistics in 2017, the average domestic per capita consumption of maize grains was 20.84 kg/year [3, 4].

Maize production is mostly carried out on dry land or in paddy fields but in the dry season following rice crops; therefore, there are many constraints in increasing maize productivity. On dry land, the most important constraint is the limited availability of soil moisture. In addition, maize plant is very high in nutrient consumption, so to increase its yield to be closer to its yield potential, high doses of fertilizers need to be applied. According to the model developed from 12 site-years of data each with 10 N rates, it was found that economic optimum rates of N fertilization ranged from 128 t0
In addition, Hammad et al. [6] reported from four N doses (150, 200, 250, and 300 kg/ha N) applied under semi-arid conditions, maize dry matter production was highest in the 300 kg/ha N dose, with an average grain yield of 7.8 ton/ha under eight times irrigation. Thus, if 300 kg/ha N is converted to Urea (45% N), then an equivalent to 667 kg/ha Urea is needed for fertilization of maize in order to get high yield.

One way of increasing maize yield is to grow it in intercropping with legume crops. Inal et al. [7] reported that maize-peanut intercropping induced changes in the rhizosphere of the intercrops making higher availability of some nutrients resulting in higher concentrations in the above-ground parts of the intercrops compared with their monocrop, such as increased in P, K and Fe, and increased root growth and chlorophyll contents of maize in intercropping with peanut compared with in monocropped maize. Wangiyana et al. [8] also reported that intercropping sweet corn with peanut could increase dry stover weight, number of green leaves, and fresh cob weight per plant at harvest. In addition to increased grain yield, Fujita et al. [9] reported significant N transfer from soybean to sorghum in an intercropping system, and the rate of N transfer was highest in the closest distance between sorghum and soybean, i.e. 12.5 cm, compared with 17.7 cm, 25 cm and 50 cm. Chu et al. [10] also reported significant N transfer from peanut to rice plants in intercropping under aerobic system. Intercropping upland red soybean was found not only to increase grain yield but also increase anthocyanin content in the grains [11]. In intercropping waxy maize with soybean or mungbean, Wangiyana et al. [12] reported that relay-planting of 1-3 rows of mungbean or soybean plants between rows of waxy maize significantly increased maize yield even though the N fertilizer dose applied to the maize plants was reduced to only half the recommended dose (50% of the recommended dose). This study aimed to examine the effects of relay-planting different number of rows of peanut between rows of maize plant at different planting distances on growth and grain yield of maize plants of two different varieties.

2. Material and Methods

2.1. Material
The materials used in this study included two maize varieties (waxy and hybrid maize varieties), peanut of Hypoma-1 variety, a compound fertilizer (NPK 15-15-15) fertilizer, Urea (45% N) fertilizer, and some systemic insecticides.

2.2. Methods
The field experiment in this study was conducted in the experimental farm of the Faculty of Agriculture, University of Mataram, located in Narmada (West Lombok, Indonesia), from June to October 2017. The experiment was designed according to Split Split-Plot design, with three blocks and three treatment factors, namely additive intercropping (I) maize with peanut as the main plots (I0= without intercropping; I1, I2, I3 = additive intercropping with 1, 2, 3 rows of peanuts); maize varieties (V) as the subplots (V1= local waxy maize, V2= Bisi-816 hybrid maize); and maize row spacing (S) as the sub-sub-plots (60, 75, 90 cm). The complete procedures used for the implementation of the experiment were as described in Wangiyana et al. [13], except for the maize varieties used.

Observation variables included plant height and number of green leaves at 9 weeks after planting (WAP), dry stover weight per m², cob length, dry grain weight (grain yield) per plant and per m², and weight of 100 dry grains of maize. Data were analyzed with analysis of variance (ANOVA) and Tukey’s HSD at 5% level of significance, using the statistical software CoStat for Windows ver. 6.303. The interaction between treatment factors is displayed with a bar graph accompanied with error bar using standard error (SE) using the method of Riley [14]. Correlation analysis between variables was conducted using Minitab for Windows Release 13.0.

3. Results and Discussion
The ANOVA results summarized in Table 1 show that among the treatment factors tested, differences in varieties of maize had significant effect the most, i.e. on almost all observation variables, except on
plant height at 9 WAP, followed by plant spacing, which shows significant effects on almost all variables except on plant height and dry grain yield per plant, while intercropping with peanut shows significant effects only on number of green leaves at 9 WAP, weight of 100 dry grains, and grain yield per plant and per m². However, there were also some two-way interaction effects, i.e. interaction between varieties and intercropping on plant height at 9 WAP, between intercropping and maize spacing on number of green leaves at 9 WAP, between maize spacing and varieties on dry stover weight per m² and cob length, and a three-way interaction effect on number of green leaves per plant at 9 WAP.

| Table 1. Summary of the ANOVA result for all observation variables |
|---------------------------------------------------------------|
| **Sources of variation**                                      |
| **I** | **V** | **V x I** | **S** | **S x I** | **S x V** | **SxVxI** |
|-------|-------|-----------|-------|-----------|-----------|-----------|
| Plant height at 9 WAP                                      | ns | Ns | * | ns | ns | ns | ns |
| Number of green leaves at 9 WAP                              | **,** | *** | * | *** | *** | ns | ** |
| Dry stover weight per m²                                     | ns | *** | ns | *** | ** | ns | ns |
| Cob length                                                   | ns | *** | ns | * | ns | * | ns |
| Dry grain yield per plant                                    | *** | *** | ns | ns | ns | ns | ns |
| Dry grain yield per m²                                       | **,** | *** | ns | *** | ns | ns | ns |
| Weight of 100 dry seeds                                      | * | *** | ns | ** | ns | ns | ns |

1) ns = non-significant; *; **; *** = significant at p < 0.05; p < 0.01; p < 0.001, respectively

Based on the results of correlation analysis between variables, it can be seen from Table 2 that grain yield per m² had a significant correlation with grain yield per plant, dry stover weight per plant (negative), number of green leaves per plant at 9 WAP and weight of 100 grains, while grain yield per plant had a significant correlation with stover dry weight per m² of plant (both negative), number of green leaves at 9 WAP, weight of 100 grains, and cob length. Interestingly, number of green leaves per plant at 9 WAP also had a positive, significant correlation with both weight of 100 grains and cob length. Therefore, the number of green leaves per plant at 9 WAP, i.e. during the grain filling stage, had significant correlation, i.e. positive, with grain yield (per m² and per plant), cob length, and weight of 100 grains, while the coefficients are negative with dry stover weight (per m² and per plant).

According to results reported by Sinclair and de Wit [15], if nitrogen supply to the growing seeds during seed filling stage is not sufficient to meet the needs of the growing seeds, then seed plants will remobilize N content of the leaves. Therefore, it is logical that number of green leaves during seed filling stage would negatively correlated with dry stover weight because higher number of green leaves would support for higher rates of grain filling and remobilization from leaves to the growing seeds, while low number of green leaves during seed filling stages would not have sufficient resources for production of photosynthate and for remobilization of nutrient from leaves to the growing seeds, which would result in relatively lower grain yield and relatively higher dry stover weight per plant.

Based on the three-way interaction effects, it can be seen from Figure 1 that numbers of green leaves per clump at 9 WAP in general was higher in intercropping with peanut than in maize monocrop, especially for the waxy maize (V1) because at that time, this variety had approaching its physiological maturity. On the other hand, growth stage of the hybrid variety (V2) was in the middle of seed-filling stage, and the highest number of green leaves at 9 WAP was in maize plants additively intercropped with three rows of peanut under 75 x 20 cm plant spacing.
Table 2. Coefficients of correlation between variables including its p-value

| Observation Variables       | Grain yield per m² | Grain yield per plant | Dry stover weight per m² | Dry stover weight per plant | Number of green leaves at 9 WAP | Plant height at 9 WAP | Weight 100 dry grains |
|----------------------------|--------------------|-----------------------|--------------------------|-----------------------------|--------------------------------|----------------------|----------------------|
| Grain yield per plant      | 0.629              |                       |                          |                             |                                |                      |                      |
| p-value                    | 0.000              |                       |                          |                             |                                |                      |                      |
| Stover dry weight per m²   | 0.222              | -0.372                |                          |                             |                                |                      |                      |
| p-value                    | 0.061              | 0.001                 |                          |                             |                                |                      |                      |
| Stover dry weight per plant| -0.316             | -0.423                | 0.738                    |                             |                                |                      |                      |
| p-value                    | 0.007              | 0.000                 | 0.000                    |                             |                                |                      |                      |
| Number of green leaves     | 0.310              | 0.590                 | -0.657                   | -0.744                      |                                |                      |                      |
| p-value                    | 0.008              | 0.000                 | 0.000                    | 0.000                       |                                |                      |                      |
| Plant height at 9 WAP      | -0.166             | 0.029                 | -0.093                   | 0.091                       | 0.095                          |                      |                      |
| p-value                    | 0.165              | 0.809                 | 0.439                    | 0.449                       | 0.429                          |                      |                      |
| Weight of 100 grains       | 0.435              | 0.322                 | -0.209                   | -0.463                      | 0.503                          | -0.095               |                      |
| p-value                    | 0.000              | 0.006                 | 0.077                    | 0.000                       | 0.000                          | 0.429                |                      |
| Cob length                 | -0.013             | 0.249                 | -0.546                   | -0.501                      | 0.586                          | 0.216                | 0.233                |
| p-value                    | 0.917              | 0.035                 | 0.000                    | 0.000                       | 0.000                          | 0.069                | 0.049                |

Figure 1. Average (Mean ± SE) number of green leaves per maize plant at 9 WAP as affected by intercropping with peanut of different number of rows, maize varieties and plant spacing

However, dry grain yield per m² was highest under the lowest plant spacing, i.e. 60 x 20 cm, probably due to the highest population per m² because grain yield was not significantly different between treatments of plant spacing (the averages are in fact almost the same between plant spacing treatments), and based on the results of data analysis, on average, grain yield per m² was significantly different between plant spacing treatments, i.e. it was the highest in maize plants grown in 60 x 20 cm followed by 75 x 20 cm, and the lowest average in maize plants grown in 90 x 20 cm plant spacing (Table 2). If we look at the average grain yield in Figure 2, it can be concluded that, if maize plants are relay-planted with peanut plants, then the best way of increasing maize grain yield per unit area, for example per m², is by reducing plant spacing and increasing the number of peanut rows relay-planted between rows of maize, especially for the waxy maize, probably due to the smaller size of leaves of the waxy maize than that of the hybrid maize.
Figure 2. Average (Mean ± SE) dry grain yield (g/m²) of maize as affected by intercropping with peanut of different number of rows, maize varieties and plant spacing

Table 3. Average plant height and number of green leaves per plant at 9 WAP, dry stover weight per m², cob length, weight of 100 grains, dry grain yield per plant and per m²

| Treatments | Plant height at 9 WAP (cm) | Green leaves per plant at 9 WAP | Dry stover weight (g/m²) | Cob length (cm) | Grain yield (g/plant) | Grain yield (g/m²) | Weight of 100 grains |
|------------|---------------------------|-------------------------------|-------------------------|----------------|----------------------|-------------------|---------------------|
| S1: 60 cm  | 197.79 ± 0.05 a           | 8.96 ± 0.05 b                 | 802.48 ± 0.05 a         | 11.79 ± 0.05 b | 72.26 ± 0.05 a       | 601.91 ± 0.05 a   | 25.56 ± 0.05 a a    |
| S2: 75 cm  | 200.33 ± 0.05 a           | 9.71 ± 0.05 a                 | 580.24 ± 0.05 b         | 12.16 ± 0.05 ab | 73.27 ± 0.05 a       | 465.23 ± 0.05 b   | 22.46 ± 0.05 b     |
| S3: 90 cm  | 207.83 ± 0.05 a           | 9.54 ± 0.05 a                 | 502.80 ± 0.05 c         | 12.33 ± 0.05 a | 73.76 ± 0.05 a       | 372.47 ± 0.05 c   | 22.61 ± 0.05 b     |
| HSD 0.05   | 10.53 ± 0.05 a            | 0.43 ± 0.05 a                 | 56.88 ± 0.05 b          | 0.49 ± 0.05 a  | 6.54 ± 0.05 a        | 45.31 ± 0.05       | 2.18 ± 0.05 a      |

V1: waxy    | 203.06 ± 0.05 a           | 7.47 ± 0.05 b                 | 761.06 ± 0.05 a         | 11.56 ± 0.05 a | 66.67 ± 0.05 a       | 435.51 ± 0.05 b   | 20.56 ± 0.05 b     |
V2: hybrid  | 200.92 ± 0.05 a           | 11.33 ± 0.05 a                | 495.95 ± 0.05 b         | 12.62 ± 0.05 a | 79.51 ± 0.05 a       | 524.23 ± 0.05 a   | 26.53 ± 0.05 a     |
| HSD 0.05   | 8.02 ± 0.05 a             | 0.57 ± 0.05 a                 | 39.82 ± 0.05 a          | 0.45 ± 0.05 a  | 4.12 ± 0.05 a        | 27.46 ± 0.05      | 2.30 ± 0.05 a      |
T0: 0 row   | 201.17 ± 0.05 a           | 8.72 ± 0.05 c                 | 604.75 ± 0.05 a         | 11.94 ± 0.05 a | 67.13 ± 0.05 a       | 440.85 ± 0.05 b   | 24.80 ± 0.05 a     |
T1: 1 row   | 202.11 ± 0.05 a           | 9.22 ± 0.05 bc                | 628.51 ± 0.05 a         | 12.02 ± 0.05 a | 70.17 ± 0.05 a       | 459.75 ± 0.05 b   | 22.69 ± 0.05 a     |
T2: 2 rows  | 203.44 ± 0.05 a           | 9.44 ± 0.05 b                 | 654.10 ± 0.05 a         | 12.44 ± 0.05 a | 69.74 ± 0.05 a       | 459.00 ± 0.05 b   | 22.96 ± 0.05 a     |
T3: 3 rows  | 201.22 ± 0.05 a           | 10.22 ± 0.05 a                | 626.66 ± 0.05 a         | 11.96 ± 0.05 a | 85.34 ± 0.05 a       | 559.90 ± 0.05 a   | 23.72 ± 0.05 a     |
| HSD 0.05   | 20.08 ± 0.05 a            | 0.65 ± 0.05 a                 | 61.75 ± 0.05 a          | 0.79 ± 0.05 a  | 7.21 ± 0.05 a        | 55.04 ± 0.05      | 2.12 ± 0.05 a      |

1) Same letters indicate non-significant deferences between levels of each treatment factor

In relation plant spacing and number of rows of peanut relay-planted between rows of maize, it can be seen from Figure 3.A that on average, maize grain yield per m² was the highest under the T3 treatment, in which three rows of peanut were inserted between row of maize of 60 cm apart. This means that the distance between maize and peanut rows and between peanut rows was 15 cm in the S1, while in the S2 it was 18.8 cm and in the S3 it was 22.5 cm. According to results reported by Chu et al. [10], there was a significant transfer of N from peanut to rice in intercropping system, and according to Inal et al. [7], intercropping maize with peanut increased availability of some nutrients in the intercrop rhizosphere when compared with in the rhizosphere of their monocrop, while according to the results reported by Fujita et al. [9], the rates of N transfer from soybean to sorghum in an intercropping system was higher when the row distance between sorghum and soybean was closer. In addition, Khan et al. [16] reported higher available and total N and available and total K in the rhizosphere of maize and peanut intercropping under 100% and 75% application of normal nitrogen dose. Based on these reports, it is logical that grain yield of maize per m² was highest in the S1 planting distance (60 cm between rows) and under T3 treatment, in which there were three rows of
peanut plants relay-planted between rows of maize of 60 cm apart. It can also be seen from Figure 3.B that grain yield of both varieties of maize per m² was highest in the lowest planting distance. This means that increasing grain yield of the maize plants can be done using the lowest row spacing accompanied with relay-planting of three peanut rows between rows of maize plants.

![Figure 3](image-url)

**Figure 3.** Average (Mean ± SE) grain yield (g/m²) of maize between combinations of intercropping and plant spacing [A], and between combinations of varieties and plant spacing [B]

In terms of grain yield of maize per unit area, several studies showed increased grain yield of maize by intercropping maize with peanut with different planting arrangements. Sutharsan and Srikrishnah [17] reported that paired rows of maize of 45/30 cm plant spacing with 30 cm within row planting, when they were relay-planted with two rows of peanut, increased maize grain yield by 13% compared with its monocropped maize. By applying different planting arrangements and using other maize and peanut varieties, from eight maize planting arrangements tested with two maize varieties, Dahmardeh [18] reported that the highest dry biomass yield of maize was obtained from plant proportions of 75% maize and 25% peanut, although different maize varieties resulted in different yield quantities, but both varieties of maize produced much higher dry biomass yield under this proportion of intercropping (37.1 ton/ha for maize var. KSC 604) compared with its monocropped maize (only 37.3 ton/ha). In addition, Olayinka et al. [19], also reported that peanut-maize intercropping of 3:1 produced the highest maize grain yield (4727.95 kg/ha) compared with its monocrop (2852.46 kg/ha), and other proportions, i.e. 3:2 and 3:3 also produced higher grain yield of maize in intercropping than in its monocrop.

Thus, all of these results showed that relay-planting one to several rows of peanut between rows of maize, either under normal row pattern or under twin-row or double-row patterns, could significantly increase maize grain yield in intercropping compared with in monocropping systems. In addition, inclusion of legume crops between rows of maize could have a significant potential for improving fertility levels of the soils compared with only growing maize plants in monocropping system, because of the potential of legume crops in fixing atmospheric N₂ through symbiosis with relevant strain of *Rhizobium* bacteria.

4. **Conclusion**

Based on the significant effect of plant spacing and intercropping with peanut, then it can be concluded that grain yield of maize can be increased by reducing plant spacing and additive intercropping with peanut, because grain yield per m² was highest under the lowest (60 cm) row spacing and intercropped with three rows of peanut, i.e. 673.34 g/m² on waxy maize (463.7 g/m² in monocrop), and 736.04 g/m² on hybrid maize (656.3 g/m² in monocrop).
References

[1] Purwono and Purnamawati H 2007 Budidaya 8 jenis tanaman pangan unggul (Jakarta: Indonesia: Penebar Swadaya)

[2] Singh N, Kaur A and Shevkani K 2014 Maize: grain structure, composition, milling, and starch characteristics pp 65-91 Chaudhary DP et al (eds) Maize: nutrition dynamics and novel uses Springer New Delhi India DOI: 10.1007/978-81-322-1623-0_5

[3] Suprapto HS and Marzuki HAR 2002 Bertanam jagung (Jakarta, Indonesia: Penebar Swadaya)

[4] BPS 2017 Kajian konsumsi bahan pokok 2017 (Jakarta Indonesia: BPS)

[5] Fageria N K, Baligar V C and Jones C A 2014 Effect of interspecific root transfer and dry matter production in soybean and sorghum mixed cropping system at different population density Soil Sci. Plant Nutr. 36(2) 233-241

[6] Hammad H M, Ahmad A, Azhar F, Khaliq T, Wajid A, Nasim W and Farhad W 2011 Optimizing water and nitrogen use for maize production under semiarid conditions. Pak. J. Bot. 43(6) 2919-2923

[7] Inal A, Gunes A, Zhang F and Cakmak I 2007 Peanut/maize intercropping induced changes in rhizosphere and nutrient concentrations in shoots. Plant Physiol. Biochem. 45 350-356

[8] Wangiyanwa, Farida N and Ngawiti 2020. Effect of peanut intercropping and mycorrhiza in increasing yield of sweet corn Paper presented in The 1st International Conference on Sustainable Tropical Land Management (ICSTLM) 16-18 September 2020 Jakarta Indonesia

[9] Fujita K, Ogata S, Matsumoto K, Masuda T, Ofosu-Budu GK and Kuwata K 1990 Nitrogen transfer and dry matter production in soybean and sorghum mixed cropping system at different population density Soil Sci. Plant Nutr. 36(2) 233-241

[10] Chu G X, Shen Q R and Cao JL 2004 Nitrogen fixation and N transfer from peanut to rice cultivated in aerobic soil in an intercropping system and its effect on soil N fertility Plant and Soil 263 17-27

[11] Wangiyanwa W, Aryana I G P M and Dulur N W D 2020 Mycorrhiza biofertilizer and intercropping with soybean increase anthocyanin contents and yield of upland red rice under aerobic irrigation systems Paper presented at the 7th International Conference on Sustainable Agriculture and Environment (ICSAE-7) 25-27 August 2020 Surakarta Indonesia

[12] Wangiyanwa W, Irwinskyah L R, Parawinata and Kisman 2020 Additive intercropping with legume crops increases waxy maize yield on vertisol riceland in Lombok, Indonesia. Rus J Agric Socio-Econ Sci. 102(6) 57-64 DOI: 10.18551/rjoes.2020-06.07

[13] Wangiyanwa W, Gunartha I G E and Farida N 2018 Response of several varieties of maize under different plant spacing to relay cropping with several rows of peanut Crop Agro 11(2) 104-112

[14] Riley J 2001 Presentation of statistical analyses Exp. Agric. Cambridge 37(1) 115-123

[15] Sinclair T R and de Wit C T 1975 Photosynthesize and nitrogen requirements for seed production by various crops. Science 189 565-567.

[16] Khan M A, Chen J, Li Q, Zhang W, Wu L, Li Z and Lin W 2014 Effect of interspecific root interaction on soil nutrition, enzymatic activity and rhizosphere biology in maize/peanut intercropping system Pak. J. Agric. Sci. 51(2) 395-406

[17] Sutharsan S and Srikrishnah S 2015 Effect of different spatial arrangements on the growth and yield of maize (Zea mays L.) and groundnut (Arachis hypogaea L.) intercrop in the sandy regosol of eastern region of Sri Lanka RevJ AgricForSci. 3(2) 16-19

[18] Dahmardeh M 2013. Intercropping two varieties of maize (Zea mays L.) and peanut (Arachis hypogaea L.): biomass yield and intercropping advantages Intl JAgricFor. 3(1) 7-11

[19] Olayinka BU, Adefalu LL, Adisa YA, Lawal AR and Etejere EO 2017 Effects of spatial arrangements of groundnut-maize intercrop on growth, yield and proximate composition of groundnut. Al-Hikmah J Pure & AppSci 5 1-7

[20]
Acknowledgment
Through this article, the authors would like to express their deepest gratitude to the Dean of the Faculty of Agriculture, as well as the Chairperson of the Institute for Research and Community Services of the University of Mataram for providing the “PNBP” research funds of 2017 budget year for conducting this research, with the contract no. 854B/UN18/LPPM/2017.