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Weed Biology and Ecology Studies: Diversity, Dominance, Population and Weed Growth and Land Use Efficiency in Intercropping Corn (Zea mays l.) with Leguminous Crops in Dryland

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Abstract: The aim of the research is to examine the effect of intercropping corn with leguminous crops on weeds and land use efficiency. The experimental research method was designed using a randomized complete block design (RCBD) with three blocks. The treatments tested were monocrop planting patterns and intercropping between corn and leguminous crops. The results of the research showed that 16 weed species were found with high species diversity, evenness, dominance, and abundance, so that there were six dominant species that existed during plant growth. Peanuts and cowpeas are suitable for intercropping with corn because they can suppress the population and growth of weeds. Soybeans, green beans, and red beans are not suitable because they are not effective in suppressing the population and growth of weeds and compete with corn, so that corn yield losses due to competition are 38.20%–40.96% and due to weed competition, they reach 62.37%–63.77%. The best ecological and agronomic land use efficiency was obtained by intercropping corn with peanuts and cowpeas, with NKL values based on dry biomass weights of 1.90 and 1.89 (NKL > 1) and dry seed weights of 1.79 and 1.78 (NKL > 1).

Keywords: Beans; Broadleaf weeds; Corn; Land use efficiency; Leguminous crops

Introduction

The productivity of corn farming in several densely populated areas such as Java is quite high, but land ownership status is less than one hectare due to the increasing conversion of agricultural land to non-agricultural land. Limited land ownership makes the application of modern technology to increase corn production more difficult (Desi et al., 2019). The narrow status of agricultural land ownership encourages farmers to intensify their efforts to increase the productivity of their farming businesses. However, the negative impact of uncontrolled intensification causes damage to the environment and natural resources which will threaten the sustainability of the corn production system (Nurhutami et al., 2021).

An alternative that can be done to overcome this problem is to increase land productivity by diversifying crops, namely planting more than one type of plant on a plot of land at the same time (Muli et al., 2023). This system is known as the multiple cropping planting pattern. This planting pattern has advantages and disadvantages. The advantage is that it can reduce the risk of crop failure, due to pest attacks or climate disturbances. The downside is that there is intraspecies and extraspecies competition which can reduce plant productivity (Ngawit, 2023).

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The multiple cropping planting pattern commonly applied by farmers is intercropping. Intercropping is a cropping pattern system that cultivates more than one type of plant planted in one place at the same time (Benny et al., 2019). Tumpangsari is a classic cropping system that aims to avoid total crop failure on dry land and has been developed on fertile land such as in technically irrigated rice fields for efficient land use and control of pests, diseases and weeds (Ngawit, 2023). The corn and soybean intercropping system can provide several benefits, namely land use efficiency, reducing pest and disease attacks, and increasing soil fertility status, especially the nutrient N and obtaining diverse crop yields (Aisyah & Herlina, 2018).

The intercropping system can also reduce the rate of weed growth and save on the use of production facilities such as seeds, fertilizer, pesticides and land use (Setiawan et al., 2022). Apart from that, according to Baraibar et al. (2018), in the intercropping system there are intercrops that function as covercrops so that they can minimize evaporation and erosion and suppress diversity, population and growth of weeds. Land use efficiency in intercropping between corn and green beans is significantly higher compared to the monocrop system with a land equivalency ratio (NKL) value greater than one (Desi et al., 2019). Intercropping between sorghum plants and peanuts, green beans For cowpeas and soybeans, the NKL value produced is more than one (>1), meaning that the planting pattern system provides profitable results (Dewi et al., 2018; Zang et al., 2015).

In order to achieve the goal of land use efficiency in an intercropping system, it is necessary to select the right types of plants, namely those that have a synergistic or mutually beneficial relationship between the intercropped plants (Andrew et al., 2022). This type of plant must have characteristics that can be planted in the same place and at the same time. For example, between corn and soybeans (Aisyah & Herlina, 2018), corn with peanuts and cowpeas (Ngawit, 2023), sorghum with peanuts, green beans, cowpeas and soybeans (Dewi et al., 2018; Palajima et al., 2012), and sweet corn plants with beans (Beny et al., 2019). Intercropping between corn and beans is believed to be able to form a mutually beneficial relationship.

This mutualistic symbiotic relationship can occur because beans have the ability to fix nitrogen from the atmosphere which is needed for corn plants. On the other hand, corn can provide shade for light-tolerant legume plants (Agus & Sarjiyah, 2021; Setiawan, 2005). Corn is a group of plants whose primary metabolism is through the C4 photosynthesis pathway with a high photosynthesis rate, has a wide range, uses water efficiently, has low photorespiration and transpiration and is able to adapt to drought stress. Beans are classified as plants with a low level of C3 photosynthesis, photosynthesis takes place at relatively lower light intensity and temperature so they are resistant to shade. According to Aisyah et al. (2018), the differences in characteristics between corn and beans mean that detrimental intracompetition does not occur. Because the level of competition between plant types is also influenced by plant characteristics (Omid et al., 2020; Sarjiyah & Setiawan, 2020).

Bean plants generally have a shrub growth form (habitus) with a dense leaf canopy, are relatively more shade tolerant, require less light and have a shallow root system so the potential for competition with corn plants is low (Chieppa et al., 2020). Beans also have a large number of leaves so they have the potential to capture sunlight that is not captured by the canopy of corn leaves, thereby reducing the evaporation of soil moisture and being able to suppress the growth and population of weeds (Scott, 2020).

The problem is that there is no comprehensive data and information on the types of legume plants that can increase land use efficiency and effectively suppress the population and growth of weeds if intercropped with corn on dry land. According to Andrew et al. (2022), on fertile land that has been managed for a long time, mixed cropping systems are on average no more productive or more effective at suppressing weeds than productive monoculture crops such as forage crops and grass. Baraibar et al. (2018), also reported that several types of legumes that are popular in the world are planted in a mixed system with corn, none of which were able to suppress the population and growth of important weeds from the Ciperaceae and Poaceae groups.

On fertile land that is intensively managed, corn, sorghum, soybeans and peanuts planted in monocrop are effective in suppressing the growth and population of weeds so that optimal productivity can be achieved, compared to productivity of 33-35% in an intercropping system (Omid et al., 2020). Even herbicides are only needed during fallow periods (John et al., 2022). Based on the descriptions above, research was carried out which aimed to increase land productivity through a system of intercropping patterns between corn and legumes. The research results hope to find a type of legume plant that is most suitable for intercropping with corn on dry land.

Method

Methods, Materials, Tools and Research Implementation

Experimental research method carried out on moorland in Tanak Gadang village, Pringgabaya District, East Lombok Regency, West Nusa Tenggara. Research implementation will start from June 2023 to October 2023.

The tools used are a hoe, sickle, hand tractor, analytical scale, oven, portable leaf area meter plant tester Brand YMJ-A, ruler, pruning shears, bucket, hand sprayer Brand Knapzak-16 l, paper envelope, bamboo, label board, rope plastic, cameras, and other supporting equipment. The materials used in this research were corn seeds of the Bisi-2 Hybrid Variety, solid organic fertilizer, urea fertilizer, ZK fertilizer and TSP fertilizer. Willis variety soybean seeds, Elephant variety peanuts, Parakeet variety green beans, local cultivar red beans and cowpeas, Desis 25 EC insecticide and Siento 550 EC fungicide.

The experiment was designed with a randomized complete block design (Randomized Completely Block Design = RCBD). The intercropping treatments tested were corn with peanuts (Jg+Kt), corn with soybeans (Jg+Kd), corn with green beans (Jg+Kh), corn with red beans (Jg+Km), and corn with cowpeas (Jg+Kg). As a comparison (control), plots were created with monoculture planting patterns for corn (Jg), peanuts (Kt), soybeans (Kd), green beans (Kh), red beans (Km) and cowpea monoculture (Kg). All treatment plots were placed using the random sampling method in 3 blocks so that there were 33 experimental units.

Tillage is carried out using a hand tractor, until the soil is loose and even. Next, treatment plots were created with a size of 3.0 m x 4.0 m, with 5 intercrop plots and 6 monocrop plots in each block. The distance between treatment plots was 30 cm and the distance between blocks was 50 cm. Fertilization was carried out after the treatment plots were completed using Vermicompost organic fertilizer at a dose of 30 tonnes ha^{-1}, which was applied by spreading it evenly on the surface of the treatment plots. The vermicompost fertilizer used contains nutrients 4.28% N, 1.55% P, and K 3.6 7%. (Beny et al., 2019). Basic fertilizer is applied before planting corn, using Urea at a dose of 100 kg ha^{-1}, TSP at a dose of 150 kg ha^{-1}, and ZK at a dose of 150 kg ha^{-1}. Additional fertilization is carried out when the plants are 21 days after planting (DAP) with Urea fertilizer at a dose of 200 kg ha^{-1}.

Corn seeds are planted in planting holes that are ± 3 cm deep, 2 grains per hole with a planting distance of 25 cm x 75 cm. Each bean plant is planted in 2 rows between rows of corn plants with a spacing of 25 cm x 25 cm. Watering the plants by means of puddles begins when the plants are 14 DAP. Subsequent watering is carried out every 10 days until the plants are 90 DAP. Plant pest control uses the insecticide Desis 25 EC, dose 1.5 l a.i. Disease control was carried out to ward off downy mildew infection using the fungicide Siento 550 EC at a dose of 2.0 l ha^{-1} with a spray volume of 500 l water ha^{-1}, which was applied when the plants were 35 DAP.

Parameter Observation and Data Analysis

The parameters observed were plant leaf area, dry plant biomass, dry biomass of weeds, dry seed weight of corn plot-1, dry seed weight of beans plot-1, number of weed species and number of weed populations. Sample plants were determined using systemic random sampling by taking 20% of the plant population in each treatment plot.

Observations on the number of weed species, population and dry biomass weight of weeds were carried out when the plants were 21, 35, 49, 63 and 77 DAP, in sample plots measuring 50 cm x 50 cm. The distribution of sample plots in each treatment plot uses a regular sampling method. The number of species and population of weed species was carried out by recording and counting them in each sample plot. The dry biomass weight of weeds was measured by weighing weed stalks that had been oven-roasted for 48 hours at a temperature of 700C, until they reached a constant dry weight.

Data analysis uses quantitative analysis of several parameters, namely, relative density (KR), relative frequency (FR) and relative dominance (DR) which are used to calculate the important value index (INP) and standard dominance ratio (SDR). The SDR value is then used to calculate several vegetation character criteria.

The species similarity index (C), is used to assess the similarity of population numbers and growth of a weed species in the two communities being compared. The community coefficient is calculated using the Formula 1 (Syahputra et al., 2011).

$$C = \frac{2W}{a+b} \times 100\% \quad (1)$$

Where, C = Community coefficient (%); W = Smaller SDR value of a weed species in the two pairs of communities being compared; a = Sum of SDR values of all weed species in the first community compared; b = Sum of SDR values of all weed species in the second community being compared.

The species diversity index (H′) is useful for studying the influence of biotic disturbances on species diversity and vegetation populations. The H′ calculation is obtained from the important value or SDR resulting from vegetation analysis, using the Formula 2 (Syahputra et al., 2011).

$$H' = -\sum_{n=1}^{n} \frac{ni}{N}\left(Ln\frac{ni}{N}\right) \quad (2)$$

Where, H′ = Shannon-Wiener diversity index; ni = SDR value of a weed species; N = Sum of SDR values for all weed species; Ln = Natural logarithm; Criteria: H′ < 1 = low species diversity; 1 ≤ H′ ≤ 3 = medium species diversity; H′ > 3 = high species diversity.

The species evenness index is useful for knowing whether each weed species has the same and even number of individuals in each community. The formula for calculating the species evenness index is as follows (Suveltri et al., 2014):

$$E = \frac{H'}{H'maks} \quad (3)$$

Where, E = Species evenness index; H' = Shabnon-wiener diversity index; H'maxs = log2 S (S is the number of weed species found); Criteria for species evenness index values: E > 0.6 = high evenness, 0.3 ≤ E ≤ 0.6 = medium evenness and E < 0.3 = low evenness.

The species dominance index is used to determine species richness and the balance of the number of individuals of each species in each compared community. The species dominance index value is calculated using the Simpson formula as follows (Palijama et al., 2012):

$$Ci = \sum_{n=1}^{n} \left(\frac{ni}{N}\right) \quad (4)$$

Where, Ci = dominance index; ni= SDR value of the nth species; N = Total SDR value of all species; The criteria for calculating the species dominance index, namely 0 < Ci < 0.05, means that there are no species that dominate the vegetation area, and 0.05 < Ci < 0.1 means that there are species that dominate the vegetation.

The value of the variable predicting the effect of weeds and legumes on corn plants is expressed as Y(DTN) which is the estimated value of Y obtained by entering the Bi and Pi values from the observations into the regression equation. In this article, the Y(DTN) value is referred to as the relative weighted dominance value which is determined from the calculation of the absolute weighted dominance value (DTM). The DTM and DTN values of plants and weeds are calculated using the following formula (Ngawit et al., 2023):

DTM= [(Dry biomass weight of nth plant) multiplied by (Number of nth plant population) divided by (Total area of all sample plots)]. times (100%)]

DTN = [(Weighted dominance value of a plant species) divided by (Total weighted dominance value of all plant species) multiplied by (100%)]

Based on the linear relationship model between the relative weighted dominance of weeds and legumes and the actual yield of corn plants, the competition index for each species of weeds and legumes can be calculated as follows (Farida et al., 2022).

$$q = \frac{\beta 1}{\beta o} \quad (5)$$

Where, q = competition index for weeds or legumes; β0 = constant; and β1 = regression coefficient.

Next, to predict corn crop yield losses due to competition from weeds and legumes, use the formula according to Kropff and Lotz (1993).

$$YL = (DTNt)q\left(\sqrt{DTNg}\right) \quad (6)$$

Where, YL = predicted corn yield loss; q = plant competition index; DTNg = weighted relative dominance of plants; and DTNt = weighted relative dominance of weed-free corn plants.

The land equivalency ratio is calculated using the following formula (Desi et al., 2019).

$$NKL = Y_{ab}/Y_{aa} + Y_{ba}/Y_{bb} \quad (7)$$

Keterangan:

Y_{ab} = Bobot berangkasan jagung tumpangsari

Y_{aa} = Bobot berangkasan jagung monocrop

Y_{ba} = Bobot berangkasan tanaman kacang tumpangsari

Y_{bb}= Bobot berangkasan tanaman kacang monocrop.

Result and Discussion

Diversity, Population and Weed Growth in Each Treatment

The data in Table 1 shows that 16 species of weeds were found, consisting of two species of sedge, six species of Poaceae weeds and eight species of broadleaf weeds. Broadleaf weeds were more dominant than poaceae and sedges in the monocrop treatment and intercropping of corn with soybeans, green beans and red beans. The reason is because the canopy of soybeans, green beans and red beans is ineffective at intercepting sunlight that passes through the corn canopy (Stephanie et al., 2020). As a result, the weed seed bank in the soil from the previous season is lifted upwards during soil processing and germinates when it gets enough water and sunlight. Then it grows into an adult weed and competes with plants (Putra et al., 2018). According to Jumatang et al. (2020), most broadleaf weeds reproduce only with seed propagules and are annual weeds and are more shade tolerant than sedge weeds and grasses, so they are able to dominate the legume crop area.

The opposite results occurred in monocrop and corn intercropping with peanuts and cowpeas, because the population and growth of broadleaf weeds were very suppressed so that their population and dominance were very low. In both treatments, sedge and poaceae weeds were dominant so that only two species of broad-leaved weeds were able to continue to grow and exist during plant growth, namely Synedrella nodiliflora L., and Amaranthus spinosus L. The resistance of these two weeds to shade and their resistance to herbicides has been reported by Seth et al. (2022), and similar findings were also reported by Dylan et al. (2023), thus strengthening the results obtained in this study.

Based on the results of calculating species similarity, diversity, evenness and dominance indices, it appears that the population, dominance and growth of broad-leaved weeds, sedges and grasses in the intercropping treatment of corn with peanuts and cowpeas is significantly lower than in other treatments. The data in Table 2 shows that the species similarity index value in the intercropping treatment of corn with peanuts (Jg+Kt) with other treatments ranged between 47.18% - 74.05% and the species similarity index value from the comparison of the corn and cowpea treatment (Jg+Kk) with other treatments ranging from 55.64% - 73.40%, which means the similarity is smaller than 75% and the difference value is greater than 25%. So it can be stated that the number of species, population and growth of weeds in the monocrop treatment and intercropping of corn with peanuts and cowpeas is significantly lower compared to the monocrop treatment and intercropping of corn with soybeans, green beans and red beans. This result is in accordance with the research results of Agus & Sarjiyah (2021), that peanuts and cowpeas as insert crops in an intercropping system with corn are more effective in suppressing the population and growth of broad-leaved weeds, sedges and paceae compared to insert crops of soybeans, peanuts. green and red beans.

Table 1. Effect of Intercropping Corn with Legumes on the Respective Average SDR Values Each Weed Species During Plant Growth (21 DAP-77 DAP)

Weed species	Average SDR value (%) for each weed species in the intercropping treatment of corn with bean plants from the age of 21 – 77 DAP										
	Cor	Pea	Soy	Grb	Reb	Cou	Cor+Pe	Cor+So	Cor+Gr	Cor+Re	Cor+Cou
C. rotondus	37.46	15.12	9.28	12.82	13.72	17.13	10.98	15.31	15.19	18.3	16.19
C. iria	5.39	5.15	7.92	17.14	16.24	14.35	13.14	12.04	11.8	12.24	9.99
P.vasginatum	16.01	17.52	31.58	14.06	12.16	14.00	10.18	9.05	11.15	13.23	10.66
L. hexandra	11.99	7.03	4.72	5.49	7.39	6.55	11.99	12.64	9.01	4.23	12.49
D. longiflora	10.51	15.84	0.89	2.13	3.13	6.28	12.53	9.74	8.84	15.36	13.84
C. dactylon	5.39	8.57	0.36	0.31	2.32	5.69	19.2	7.64	5.00	7.00	11.70
E. indica	4.67	5.22	9.17	3.52	2.52	5.55	4.47	7.52	4.37	5.54	8.89
D. Ciliaris	0.00	8.98	5.21	6.64	4.33	6.00	9.18	6.41	5.77	0.00	6.12
S. nodiliflora	5.34	6.47	1.45	4.20	5.34	4.30	4.69	3.21	4.32	5.52	4.86
A. spinosus	3.24	0.61	6.83	8.86	7.73	3.87	3.65	4.61	4.2	6.18	5.26
H. herbacea	0.00	2.86	1.42	1.93	3.73	3.70	0.00	3.12	3.65	3.22	0.00
C.rutidosperma	0.00	0.00	3.01	8.46	7.64	3.63	0.00	2.21	3.05	3.54	0.00
P. niruri	0.00	1.39	2.61	5.75	3.53	3.06	0.00	2.12	2.84	0.00	0.00
P. oleracea	0.00	0.00	8.79	4.67	4.54	2.81	0.00	1.13	4.23	2.22	0.00
A.phlloxeroides	0.00	3.71	6.78	4.02	4.24	2.44	0.00	1.12	4.03	0.00	0.00
P. angulata	0.00	1.53	0.00	0.00	1.13	0.65	0.00	1.13	2.55	2.42	0.0

Description: Cor, Pea, Soy, Grb, Reb and Cou = monocrop corn, peanuts, soybeans, green beans and cowpeas; Cor+Pe, Cor+So, Cor+Gr,Cor+Re and Cor+Cou = intercropping corn with peanuts, soybeans, green beans, red beans and cowpeas

Monorope treatment and intercropping of peanuts and cowpeas with corn causes a significant increase in the growth of the plants themselves so that their retention is stronger in suppressing the growth and population of weeds. Scott (2020), reported similar results that biomass from cover crops can effectively suppress the growth of the annual weed Gulongan Poaceae. Legume biomass also increases varying soil porosity, due to increased levels of organic matter and increased activity of microorganisms such as phosphorus solubilizing bacteria and Rhizobium (Chieppa et al., 2020). Increased soil porosity in response to the influx of organic matter from weathering groundnut and cowpea leaves makes for a healthier plant growing environment, which will ultimately support better corn growth (Stephanie et al., 2020). Corn, peanuts and cowpeas with ideal growth performance effectively suppress the growth and population of weeds from both the poaceae, sedge and broadleaf groups. This is shown by the data in Table 1, that weed population, dominance and growth as depicted in the SDR calculation results for each weed species, are always the lowest in this treatment. However, for the 2 puzzle species and 4 poaceae species that were observed during plant growth, it seems that this treatment did not work better than the other treatments.

The ability of corn intercropping treatment with peanuts and cowpeas to suppress weed population and growth is also seen in Table 3, that weed diversity is in the low category with a diversity index value of 0.76 – 0.77. Meanwhile, in the monocrop treatment and intercropping of corn with soybeans, green beans and red beans, the values obtained were 2.14 – 3.21, which is in the high category. According to Nanlohy et al. (2024), the Shannon-Wiener diversity index (H') value of 1.75-2.00 is in the medium category and more than 3.00 is in the high category (Ngawit et al., 2023).

The finding of high diversity is in line with the results of the evenness index (E) calculation obtained, including the high category in the monocrop treatment and intercropping of corn with soybeans, green beans and red beans, which ranges from 0.82 – 0.84. Meanwhile, what was obtained from intercropping corn with peanuts and cowpeas was 0.562 – 0.582. This value is smaller than 0.60, which means it is in the low category, so it can be stated that the ability to spread weed species in the intercropping treatment between corn with peanuts and cowpeas is low. Because according to Fanisah et al. (2023), the spreading ability of weed species is high, if the species evenness index value is greater than 0.60.

Table 2. Similarity Index Values, Population and Growth of Weed Species (%) in Each Monocrop Treatment and Intercropping Between Corn and Legumes on Dry Land

Treat-ment	Weed species similarity and growth index value (%)										
	Cor	Pea	Soy	Grb	Reb	Cou	C+P	C+S	C+G	C+R	C+Co*)
Cor	-	69.83s	66.86s	71,21s	64.58s	66.95s	68.29s	78.05ns	66.51s	53.28s	73.40s
Pea	69.83s	-	59.53s	63.98 s	65.95s	72.17s	73.19s	75.87ns	76.85ns	78.83ns	68.96s
Soy	66.86s	59.53s	-	69.92s	68.24s	65.54s	48.13s	60.30s	64.85s	42.50s	54.64s
Grb	71.21s	63.98s	69.92s	-	89.59ns	80.65ns	60.24s	68.10s	77.46ns	76.55ns	60.50s
Reb	64.58s	65.95s	68.24s	89.59ns	-	83.54ns	62.33s	75.13ns	83.81ns	75.95ns	64.18s
Cou	66.95s	72.17s	65.54s	80.56ns	83.54ns	-	71.24s	83.90ns	89.72ns	82.14ns	70.08s
C+P	68.29s	73.19s	48.13s	60.24s	62.33s	71.24s	-	47.18ns	74.00s	69.70s	70.67s
C+S	78.05ns	75.87ns	60.30s	68.10s	75.13ns	83.90ns	47.18s	-	87.27ns	75.92ns	67.28s
C+G	66.51s	76.85ns	64.85s	77.46ns	83.81ns	89.72ns	74.00s	87.27ns	-	80.01ns	67.35s
C+R	53.28s	78.83ns	42.50s	76.55ns	75.95ns	82.14ns	69.97s	75.92ns	80.01ns	-	67.57s
C+Co	73.40s	68.96.s	54.64s	60.50s	64.18s	70.08s	70.67s	67.28ns	67.35ns	67.57ns	-

Note:
*) Species similarity index values equal to or greater than 75% are not significantly different (ns) due to similar numbers; the population and growth of weed species are greater than 75%, and the difference is less than 25%.
*) Cor, Pea, Soy, Grb, Reb and Cou = monocrops of corn, peanuts, soybeans, green beans and cowpeas.
*) C+P, C+S, C+G, C+R, C+Co = intercrop corn with peanuts, soybeans, green beans red beans and cowpeas.

The high diversity and ability to spread of weeds influences the ability of weeds to dominate corn and bean planting areas. This is shown by the data in Table 3, that the dominance index value in all monocrop treatments and corn intercropping with legumes is always greater than 0.1 (Ci > 0.1) and the weed abundance index value is greater than 85% (Di > 85%) . This means that weed species from the sedge, poaceae and broadleaf groups are always dominant and abundant, in all treatments. So the diversity and ability to spread, dominate and abundance of weed species in the monocrop treatment and intercropping of corn with soybeans, green beans and red beans is in the high category. So there are 6 species of weeds out of 16 species found, always dominant (SDR> 10%) and existing during plant growth, namely 1 species of cyperus rotundus L., 4 species of poaceae Paspalum vasginatum Sw., Leersia hexandra Sw., Digitaria longiflora (Retz.) Koel., and Cynodon dactylon L. and 2 broad-leaved species, namely Synedrella nodiflora (L.) Gaertn. and Amaranthus gracilis Desf. Some of these weed species are called noxious and invasive weeds, because of their diversity, distribution, dominance and ability to be highly abundant, so that they remain dominant and exist as long as the plant grows, even though they are under shade pressure from the plant canopy (Sarah et al., 2022). Some weed species are also tolerant to herbicides (John et al., 2022) and shade from the dense canopy of corn plants, which can reduce corn yields by up to 25% (Ngawit, 2023).

Table 3. Index Values for Diversity, Evenness, Dominance, and Abundance of Weed Species in Each Monocrop Treatment and Intercropping between Corn and Legume Plants in Dry Land

Treatmen	Species index value			
	Diversity Index (H')	Evenness Index (E)	Dominance Index (Ci)	Abundance Index (Di)
ocrop corn	2.140	0.832	0.2421	88.77
Monocrop peanuts	0.772	0.582	0.1344	85.31
Monocrop soybeans	3.201	0.844	0.2134	89.64
Monocrop green beans	3.211	0.833	0.2242	89.36
Monocrop red beans	0.821	0.581	0.1261	86.11
Monocrop cowpea	0.774	0.572	0.1322	86.46
Intercrop corn with peanuts	0.762	0.574	0.1333	85.12

Treatmen	Species index value			
	Diversity Index (H')	Evenness Index (E)	Dominance Index (Ci)	Abundance Index (Di)
Intercropping corn with soybeans	3.210	0.831	0. 2201	89.74
Intercrop corn with peanuts	3.311	0.834	0.2342	87.84
Intercrop corn with red beans	3.202	0.802	0.2141	88.32
Intercrop corn with cowpeas	0.763	0.562	0.1112	85.62

The Effect of Intercropping Corn with Legumes on the Growth and Yield of Corn Plants and Land Use Efficiency

The more suppressed weed population and growth in the monocrop treatment and intercropping of corn with peanuts and cowpeas had a positive effect on the growth of plant leaf area. The data in Table 4 shows that when the plants were 21 – 49 DAP the leaf area of legume plants intercropped with corn was not significantly different from the leaf area planted in monocrop. When the plants were 63 - 77 DAP, the leaf area of monocrop and intercropping corn with peanuts and cowpeas was significantly larger than the leaf area of monocrop and intercropping corn with soybeans, green beans and red beans. The reason is because more and more soybean, red bean and green bean leaves fall after the plants are 63 DAP, as a result the total number of leaves decreases. Bolly (2018), states that the number and area of leaves have a direct effect on the leaf area index, the existence of which is predominantly influenced by the plant's growing environment, one of which is sunlight.

Table 4. Effect of Monocrop Planting Patterns and Intercropping of Corn with Legumes on Leaf Area Monocrop and Intercrop when the Plants are 21 DAP - 77 DAP

	Leaf area (cm^2)				
	21 DAP	35 DAP	49 DAP	63 DAP	77 DAP
Monocrop corn	228.63 a	441.33 a	671.24 a	1501.62 a	1614.72 a
Monocrop peanuts	200.22 a	432.41 a	628.74 a	1495.77 a	1442.41 a
Monocrop soybeans	156.22 b	347.74 b	534.62 b	588.84 b	850.62 b
Monocrop green beans	154.75 b	344.82 b	631.74 a	594.64 b	865.22 b
Monocrop red beans	152.74 b	314.66 b	388.74 d	564.71 b	832.74 b
Monocrop cowpea	199.83 a	442.74 a	633.81 a	1502.66 a	1511.74 a
Intercrop corn with peanuts	196.71 a	398.74 a	654.33 a	1545.61 a	1642.31 a
Intercropping corn with soybeans	150.44 b	306.77 b	399.22 c	403.42 c	636.81 c
Intercrop corn with peanuts	151.81 b	300.22 b	514.72 b	422.84 c	662.44 c
Intercrop corn with red beans	148.72 b	298.73 b	382.61 d	397.64 c	701.64 c
Intercrop corn with cowpeas	198.64 a	438.66 a	664.33 b	1528.22 a	1514.43 a
LSD 0.05	29,744	88.664	48.772	42.773	111.233

Note: Numbers in the same column followed by the same lower case letter are not significantly different in the LSD0.05 test.

The more surface area the leaf has, the more solar energy is absorbed, so that the photosynthesis process takes place optimally. The more photosynthesis the process, the more photosynthesis that can be produced for plant growth and development (Kantikowati et al., 2022).

These results are in accordance with the results obtained in the monocrop treatment and intercropping of corn with peanuts and cowpeas, namely that the dry biomass weight and growth rate of dry biomass weight of corn since the plants were 21-77 DAP were significantly higher compared to other treatments (Table 5). The suppressed weed population and growth in the two intercropping treatments means that the plants do not experience competition in utilizing growth factors compared to conditions where the plants are shaded by weeds and have limited growing space. Kresnatita et al. (2018), stated that in optimal growth room conditions, photosynthesis runs optimally so that it has an impact on the size, number of cells, and the development of intercellular cells. As a result, the number and size of plant stems, leaves and roots increase, which is ultimately reflected in the dry biomass weight (Herlina & Prasetyorini, 2020).

The high weight of dry plant biomass produced by intercropping corn with peanuts and cowpeas causes the Land Equity Ratio (NKL) index value to be significantly higher than that obtained from intercropping corn with soybeans, green beans and red beans. This finding is in line with the observations put forward by Andrew et al. (2022).

The data in Table 6 shows that the NKL index based on dry plant biomass in the intercropping treatment of corn with peanuts and cowpeas is 1,891 and 1,895 respectively (NKL > 1), which means it is ecologically efficient. The same results were obtained based on dry seed weight, in the intercropping treatment of corn with peanuts and cowpeas, respectively 1,792 and 1,778 (NKL > 1), which means it is agronomically efficient. These results are similar to the research results of Wangiyana et al. (2018), that a larger plant population at a planting distance of 60 cm x 20 cm produces a higher dry weight of corn plants (ton ha^{-1}) compared to a small plant population at a planting distance of 75 cm x 20 cm and 90 cm x 20 cm.

Table 5. Effect of Intercropping Corn with Legumes on Dry Biomass Weight of Corn and Growth Rate Since the Plants were 21, 35, 49, 63 and 77 DAP

Treatment	Dry biomass weight of corn plants (gram plot^{-1})					Cbdwgr
	21 DAP	35 DAP	49 DAP	63 DAP	77 DAP	(g day $^{-1}$)
Monocrop Corn	25.420 a	78.210 a	178.953 a	281.846 a	289.026 a	5.016 a
Intercropping corn with peanuts	24.833 a	75.833 ab	140.360 b	251.150 b	286.570 a	4.550 a
Intercropping corn with soybeans	26.450 a	32.363 c	51.190 c	167.286 c	181.643 c	0.970 b
Intercrop corn with green beans	24.716 a	21.117 d	11.307 e	114.170 d	115.876 d	0.326 b
Intercrop corn with red beans	25.340 a	31.593 c	21.513 d	111.240 d	116.640 d	0.396 b
Intercrop corn with cowpeas	25.470 a	72.560 b	139.000 b	249.977 b	283.643 a	4.643 a
LSD 0.05	5.214	4.419	6.664	4.658	18.332	1.224

Note: Numbers in the same column followed by the same lower case letter are not significantly different in the $LSD_{0.05}$ test.

The highest NKL value based on dry seed weight was produced by peanut and cowpea insert plants and was significantly different from soybean, green bean and red bean insert crops (Table 6). These results are supported by the plant population (sample plot tree-1), plant growth components such as leaf area and plant dry biomass weight which in the intercropping treatment of corn with peanuts and cowpeas was higher compared to other intercropping treatments (Agus & Sarjiyah, 2021).

Table 6. Effect of intercropping corn with beans on land equivalent ratio (LER), weight corn dry shelling and corn plant population (tree 5 sample plot^{-1})

Treatment	$LER_{(Dry\ weight)}$	$LER_{(weight\ of\ dry\ shelled\ corn)}$	Dry flaking weight (g m^{-2})	Corn plant population (tree 5 sample plot-1)
Monocrop Corn	1.73 b	1.69 b	671.68 b	30.00 a
Intercropping corn with peanuts	1.89 a	1.79 a	687.66 a	30.00 a
Intercropping corn with soybeans	0.72 b	0.52 c	356.11 c	22.,33 a
Intercrop corn with green beans	0.41 c	0.43 d	75.85 d	20.66 b
Intercrop corn with red beans	0.42 c	0.42 d	54.67 e	17.66 d
Intercrop corn with cowpeas	1.90 a	1.78 a	684.28 a	30.00 a
LSD 0.05	0.87	0.40	56.05	6.2959

Note: Numbers in the same column followed by the same lower case letter are not significantly different in the $LSD_{0.05}$ test.

The data in Table 7 shows that intercropping corn with peanuts and cowpeas gives a higher DTN value for corn compared to corn DTN in the intercropping treatment of corn with soybeans, green beans and red beans. Based on the results of calculating the competition index for each weed species, it turns out that the weeds C. rotundus, P. vasginatum, L. hexandra, and D. longiflora, have the highest competition index, so their ability to reduce corn yields is higher compared to other species during growth. plant. Corn crop yield losses in the corn intercropping treatment with soybeans, green beans and red beans were higher than in the corn intercropping treatment with peanuts and cowpeas. The total loss of corn yield due to competition from dominant weeds in the intercropping treatment of corn with peanuts and cowpeas was 43.44% - 46.39%. Meanwhile, in the intercropping treatment of corn with soybeans, green beans and red beans, the total loss of corn crop yields reached 62.56% - 63.77% (Table 8).

The weeds that caused the most crop yield losses were C. rotondus (5.50% - 5.84%), P. vasginatum (5.39% - 9.67%), D . longiflora (4.86% - 7.69%) and L. hexandra (5.19% - 8.45%). Meanwhile, five other weed species, namely, D. ciliaris, S. nodiflora, A. gracilis, P. angulata, P. longifolia and P. niruri, caused slight yield losses in corn plants, namely less than 3%. These five weed species are annual weeds and cannot tolerate shade. Dominant when corn plants are still young (10 - 20 DAP). According to Suveltri et al. (2014), the population and growth of annual weeds in corn plants decreases as the age of the plant increases. A denser corn canopy can suppress the growth of weeds underneath because of the low intensity of sunlight received by weeds between the rows of corn plants (Zhao et al., 2020).

Mulch and ground cover from legume plants can also provide the same effect as reported by Purba et al. (2023), and similar findings were reported by Omid et al. (2020), thus strengthening the results obtained in this study. According to Baraibar et al. (2018), the presence of several weed species does not always harm cereal crops such as corn, wheat and sorghum. The presence of several species of annual weeds in the peak period of the plant's life cycle and in the period leading up to harvest has very little effect, so it does not need to be controlled (Kara et al., 2020; Sarah et al., 2022).

Table 7. Value of Relative Weighted Dominance (RWD) and Competition Index for Weed Species and Intercropping Plants in the Treatments Intercrop Corn with Legumes

Species Weeds and intercropping plants	RWD value (%) and competition index for weeds and intercropping plants in the treatments intercrop corn with legumes									
	Corn+ peanuts		Corn+ soybeans		Corn + green beans		Corn+ red beans		Corn+ cowpeas	
	β	RWD	β	RWD	β	RWD	β	RWD	β	RWD
Corn	0.0000	34.72	0.0000	20.64	0.0000	21.93	0.0000	22.83	0.0000	35.80
Peanuts	0.0150	7.62	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
Soybeans	0.0000	0.00	0.0268	11.96	0.0000	0.00	0.0000	0.00	0.0000	0.00
Green beans	0.0000	0.00	0.0000	0.00	0.0269	12.86	0.0000	0.00	0.0000	0.00
Red beans	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0268	11.96	0.0000	0.00
Cowpeas	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0166	8.22
C. rotondus	0.0180	9.34	0.0266	7.85	0.0266	8.65	0.0266	8.65	0.0200	8.54
C. iria	0.0170	4.32	0.0224	2.49	0.0224	2.50	0.0224	2.50	0.0200	4.43
P.vasginatum	0.0180	8.96	0.0276	12.27	0.0276	11.27	0.0276	11.20	0.0211	11.22
L. hexandra	0.0180	8.34	0.0254	10.07	0.0254	11.07	0.0254	10.06	0.0210	7.64
D. longiflora	0.0170	8.16	0.0254	9.11	0.0254	8.10	0.0254	9.17	0.0210	7.72
C. dactylon	0.0170	5.16	0.0240	7.02	0.0240	7.03	0.0240	7.04	0.0180	6.22
E. indica	0.0180	2.42	0.0236	7.64	0.0236	7.44	0.0236	7.50	0.0181	1.54
D. Ciliaris	0.0180	2.31	0.0235	3.06	0.0235	2.26	0.0235	2.20	0.0181	1.30
S. nodiliflora	0.0170	3.74	0.0222	3.19	0.0222	3.29	0.0222	3.26	0.0170	2.44
A. spinosus	0.0170	2.66	0.0222	4.34	0.0222	3.24	0.0222	3.27	0.0160	2.54
P. niruri	0.0170	1.21	0.0220	0.22	0.0221	0.21	0.0221	0.20	0.0162	1.24
P.angulata	0.0160	1.04	0.0220	0.14	0.0221	0.15	0.0221	0.16	0.0170	

Note : RWD = relative weighted dominance (%); β = Competition index

Loss of corn yield (YL) due to competition from peanut inserts was 4.14% and cowpea 4.76%. Meanwhile, the result of competition was 9.27% for soybeans, 9.64% for green beans and 9.26% for red beans. The high loss of corn yield due to competition from soybean, green bean and red bean insert crops is because the competition index and relative weighted dominance (DTN) of these three insert crops are higher compared to the competition index and DTN of peanuts and cowpeas (Andrew et al., 2022). In addition, important and dangerous weeds such as C. rotondus, P. Vasginatum, D. longiflora and L. hexandra in the soybean, green bean and red bean insert crop treatments were not suppressed in population and growth, so they still had high competitiveness against corn plants.

According to Kara et al. (2020), these four weeds have high competitive power in various types of agricultural land management so they are also called invasive weeds. Scott (2020), also reported that only mulch and legume cover crop (LCC) shading pressure were effective in suppressing the population and growth of these four noxious and invasive weed species.

Table 8. Yield Loss of Corn (YL) Due to Competition between Weed Species and Intercropping Plants in the Treatments Include Intercropping Corn with Legumes

Species Weeds and intercropping plants	Yield loss of corn [YL (%)]				
	Corn+ peanuts	Corn+ soybeans	Corn + green beans	Corn+ red beans	Corn+ cowpeas
Corn	4.14	0.00	0.00	0.00	0.00
Peanuts	0.00	9.27	0.00	0.00	0.00
Soybeans	0.00	0.00	9.65	0.00	0.00
Green beans	0.00	0.00	0.00	9.27	0.00
Red beans	0.00	0.00	0.00	0.00	4.76
Cowpeas	5.50	7.45	7.82	7.82	5.85
C. rotondus	3.53	3.53	3.54	3.54	4.21
C. iria	5.39	9.67	9.27	9.24	7.07
P.vasginatum	5.20	8.06	8.45	8.06	5.81
L. hexandra	4.86	7.67	7.23	7.69	5.84
D. longiflora	3.86	6.47	6.36	6.37	4.49
C. dactylon	2.80	6.52	6.44	6.46	2.25
E. indica	2.74	4.11	3.53	3.49	2.06

Species Weeds and intercropping plants	Yield loss of corn [YL (%)]				
	Corn+ peanuts	Corn+ soybeans	Corn + green beans	Corn+ red beans	Corn+ cowpeas
D. Ciliaris	3.29	3.97	4.03	4.01	2.66
S. nodiliflora	2.77	4.62	3.99	4.01	2.55
A. spinosus	1.87	0.95	0.93	0.99	1.80
P. niruri	1.63	0.76	0.78	0.88	1.82
P.angulata	43.44	63.77	62.37	62.56	46.39

Note : Corn+ peanuts, Corn+ soybeans, Corn + green beans, Corn+ red beans, Corn+ red beans, and Corn+ cowpeas = Intercropping corn with peanuts, Intercropping corn with soybeans, Intercropping corn with green beans, Intercropping corn with red beans, and Intercropping corn with cowpeas

Several gumla species are reported to be tolerant to various post-emergence herbicides (Dylan et al., 2023). The application of agroresidual mulch from legume plants and abrasive sand, in the weed germination phase, significantly reduces corn crop yield losses due to the weeds C. rotondus and D. sanginalis (Forcella et al., 2020). This finding is in line with the results of this study regarding low corn yield losses in peanut and cowpea insert crop treatments due to suppressed population and growth of sedge and poaceae weeds. The dominant weeds found in the intercropping treatment plots of corn with peanuts and cowpeas were soft weeds such as L. parviflor, P. longifolia, P. angulata, P. Oleracea, P. niruri and H. indicum, which grew with low competitiveness, so Corn plants make maximum use of nutrients, water, light, CO_2 and available growing space. As a result, the sprouts of sedge weeds and grasses cannot grow and develop due to the pressure of shade from the corn plants and soft weeds.

Conclusion

There were 16 weed species found with high species diversity, evenness, dominance and abundance. There were six species that were dominant and existed during plant growth, namely C. rotundus, P vasginatum, L. hexandra, D. Longiflora, S. nodiflora and A. Gracilis. Corn is suitable for intercropping with peanuts and cowpeas, while soybeans, green beans and red beans are not suitable because they are not effective in suppressing the population and growth of weeds, and compete with corn, so the loss of corn yield due to competition is 38.20% - 40.96% and Corn crop yield losses due to weed competition reached 62.37% – 63.77%. The best ecological and agronomic land use efficiency was obtained by intercropping corn with peanuts and cowpeas, with NKL values based on dry biomass weight of 1.90 and 1.89 (NKL > 1) and based on dry seed weight of 1.79 and 1.78 (NKL > 1).

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Author Contributions

Conceptualization, I.K.N. and IWS; methodology, I.K.N., I.W.S. and I.W.Sn.; formal analysis, I.K.N. and I.W.Sn.; investigation, I.K.N., I.W.S. and I.W.Sn.; resources, I.K.N., I.W.S. and I.W.Sn.; writing—preparation of original draft, I.K.N.; writing—reviewing and editing, I.W.S. and I.W. Sn.; visualization, IWS; supervision, I.W.Sn.; project administration, IKN; obtaining funding, I.K.N. and I.W.S. All authors have read and approved the published version of the manuscript.

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