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Weed Biology and Ecology Studies: Diversity, Dominance and Prediction of Yield Loss of Corn (*Zea mays* L.) Due to Broadleaf Weeds Competition in Dryland

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Abstract: The aim of the research was to determine the diversity, distribution, dominance, and yield loss of corn due to competition from broadleaf weeds. Descriptive research method with direct survey techniques of research objects. Data were collected using 10 sample plots measuring 1 m^2, which were placed using random sampling. Observation parameters include the population and dry biomass weight of weeds and corn. The data was analyzed descriptively and comparatively by calculating density, frequency, and dominance to obtain an important value index and summation diminance ratio (SDR). The results of the research showed that 14 species of broad-leaved weeds were found with high species diversity, distribution, dominance, and abundance indices. The competitiveness and relative weighted dominance of six weed species, namely Amaranthus spinusus, Amaranthus gracilis, Synedrella nodiliflora, Acalypha indica, Ageratum conyzoides, and Alternanthera philoxeroides, are higher than those of other weed species, causing corn yield losses of 5.56%–21.90%. Therefore, these six weed species must be controlled.

Keywords: Broadleaf weeds; Competition; Competitiveness; Diversity; Yield loss

Introduction

Corn products are one of the second staple food commodities in Indonesia, which are widely cultivated by farmers after rice. Since 2020, there has been a significant increase in planting area and corn production compared to previous years. However, the corn harvest area in 2023 will be 2.49 million hectares, a decrease of 0.28 million hectares or 10.03 percent compared to the harvest area in 2022 which will be 2.76 million hectares. Production of dry shelled corn with a moisture content of 14 percent in 2023 will be 14.46 million tons, a decrease of 2.07 million tons or 12.50 percent compared to 2022 which was 16.53 million tons (BPS, 2023).

Based on the development of national corn production, the West Nusa Tenggara (NTB) Provincial Government has designated corn as a superior development program in the regional agricultural sector. This policy is the right step because apart from having sufficient land potential, corn is a plant that is quite easy to cultivate, is resistant to drought stress, does not require a lot of water, and is more resistant to pest and disease attacks (Ngawit et al., 2022).

From 2020 until this last year, corn production in NTB has increased quite significantly, namely an average of 35% year^{-1} (Director General of Food Crops, 2020). Corn production in NTB province in 2020 only reached 196,237 tons. Then in 2022 it shows a quite significant increasing trend, namely 642,674 tons and in 2023 it reaches 874.34 tons. This quite high increase in corn yields, apart from the increase in planting area, was also obtained from the contribution of increasing plant productivity which reached an average of 5.4 tons ha^{-1} (BPS, 2023). The average corn production of 5.4 tons ha^{-1} achieved in the NTB area is still insufficient,

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considering that nationally the average corn production can reach 7.64 tons ha^{-1} (Setiawan et al., 2022).

The low corn production in NTB compared to the national average production is thought to be related to the quality of the growing environment and the varieties planted. Many factors determine the optimal productivity of corn yields, such as soil fertility, pests, disease, weeds and climate. According to Maharani et al. (2018), in general climate, especially temperature, rainfall, and sunlight intensity greatly determines the growth of corn plants. From a climate aspect, almost all regions in Indonesia are suitable for producing corn. The availability of soil nutrients for the growth of corn plants also greatly determines the success of corn cultivation. Another important factor that influences corn productivity is weeds (Ahmed et al., 2011; Obeng-Bio et al., 2020).

Weeds are plants that grow undesirably on cultivated plants that are being cultivated at a certain place and time. Weeds are nuisance organisms whose presence in corn planting areas, apart from causing crop yield loss, can also reduce seed quality (DeSimini et al., 2020). The reduction in crop yield due to competition with weeds is very dependent on the type of weed, density, and length of competition caused by weeds (Creech et al., 2018). If no control is carried out, yield losses caused by weeds exceed yield losses caused by pests and diseases (Blum et al., 2000; Jordan et al., 2024). Weeds as plant pest organisms (OPT) are one of the important obstacles that must be overcome in increasing corn production. The level of problems caused by weeds in corn plants varies, depending on the type of soil, temperature, altitude, planting method, water management and weed control techniques. Corn plants tend to produce high yields if they are free from weeds during their growth (Ngawit et al., 2021).

In general, weeds found in cultivated plants are grouped into three groups, namely puzzles, grasses and broad leaves (Ngawit et al., 2023). Each group has different characters, both in terms of morphology and ecology (Ilham, 2014). Although broadleaf weeds are similar in several ways, each species has specific morphological characteristics. This difference causes the broad-leaf weed canopy to retain smaller droplets from the nozzle so that herbicide penetration is not on target (Creech et al., 2018). The presence of thick fine hairs on the leaves and stems of Waterhemp weed (*Amaranthus tuberculatus*) means that the S-metolachlor herbicide sprayed post-emergence does not work (Dylan et al., 2023). The control approach of spraying VLCFA-inhibiting herbicides preemergence was found to be effective in suppressing the population and growth of Waterhemp weeds, so that the dry corn seed yields obtained were economically profitable (Strom et al., 2022). Farida et al. (2022), found that the weeds *Partherium hysterophorus, Commelina bengalensis, Portulaca oleraceae* and *Physalis angulata* were able to suppress the population and growth of sedge weeds in young corn plants. Also reported by Suryaningsih et al. (2014), there are several species of broad-leaved weeds that are always dominant in corn, including *Amaranthus spinosus, Amaranthus gracilis, Synedrella nodiflora, Ageratum conyzoides and Phylantus niruri.* Some of these weed species, according to Ngawit et al. (2022), can suppress the population and growth of forage grasses on rangelands, thereby reducing the quality of forage as a source of animal feed. Also reported by Chieppa et al. (2020), broad-leaf weed canopies that shade pastures significantly reduce forage biomass above ground. In shallot plants, only silver black plastic mulch and rice straw mulch are effective for controlling these weeds (Purba et al., 2023).

However, there has been no comprehensive report regarding the broad-leaf weed species that cause the most damage and yield reduction in corn plants. For this reason, research was carried out which aimed to identify and describe the diversity, distribution and dominance of broad-leaf weeds in corn plants in dry land. It is hoped that the results of the research will reveal broad-leaf weed species that do not cause damage or loss of corn yields, so that they can be used as a basis for consideration in efforts to control weeds in jegung crops on dry land.

Method

Research Methods, Time, Materials and Tools

The research method used is a descriptive method with direct observation of research objects in the field. The research was conducted in Mumbul Sari Village, Bayan District, North Lombok Regency, West Nusa Tenggara Province. Research will be carried out from June 2022 to October 2022.

The tools used in this research were hoes, sickles, knives, chopsticks, analytical scales, meters or rulers, scissors, buckets, plastic trays, envelopes, bamboo, label boards, neat ropes, cameras, and stationery and other supporting tools. Meanwhile, the materials used in this research were corn seeds of the Bisi-2 Hybrid Variety, Urea fertilizer, TSP fertilizer, ZK fertilizer, solid organic fertilizer, Furadan-3G, Desis 25 EC insecticide, Marsal surfactant and Citowet adhesive.

Implementation of Research and Data Collection Techniques in the Field

Soil processing is carried out to improve drainage, level the surface of the soil and clean the soil from the remains of plant organs, in order to obtain a layer of soil that is suitable and loose for cultivating corn. Land cultivation is carried out minimally with one plow and one harrow. Then the land was leveled and three (3) beds were made measuring 25 m wide and 50 m long, with a bed height of 30 cm and a distance between the beds of 1-1.5 m. Basic fertilization is carried out after making the beds with 150 kg ha^{-1} TSP fertilizer, 150 kg ha^{-1} ZK, and 250 kg ha^{-1} Urea fertilizer, specifically 0.5 doses of Urea fertilizer are applied as basic fertilizer and the rest as supplementary fertilizer after the plants are 21 years old HST. Organic fertilizer uses cow manure which is applied during soil processing at a dose of 30 tons ha^{-1}. Planting is carried out with a spacing of 75 x 25 cm, 2 seeds are planted per hole. The time for planting seeds is accompanied by applying basic fertilizer at a distance of 5 cm from the seed bed. Irrigation is carried out by flooding, which is carried out every 2 weeks when the soil moisture level is close to dry and dry temporarily, until it reaches the field capacity soil moisture level. Weeding is not done, all types of weeds are allowed to grow while the corn plants are growing. Pest control was carried out against grasshopper and leaf caterpillar attacks chemically using Coracorn insecticide at a dose of 1.5 l a.i with a spray volume of 750 l water ha^{-1}, which was applied when the plants were 20 HST, 50 HST and 75 HST. Disease control was not carried out because no symptoms of disease infection were found during plant growth.

Data collection in the field was carried out using survey techniques with direct observation of the population and growth of weeds and corn plants. Data collection began when the plants were 30 HST, and subsequent observations were carried out every 15 days until the plants were 90 HST. The distribution of sample plots was carried out using a systematic random sampling method directed at diagonal lines of the corn plot, without paying attention to the condition of the weed population at the research site. Sample plots were placed at 10 different points with a size of 1 m^2. Because each observation was carried out by taking weeds and corn plants in a destructive manner, the sample plot points for further observation were moved to areas where the plants were still intact. The weed species found in each sample plot through visual observation of the population were counted and each species was photographed for further identification (Fanisah et al., 2023). The parameters observed included the number of broadleaf weed species, the population of each weed species, the population of corn plants, the dry biomass weight of weeds, the dry biomass weight of corn plants and the dry weight of corn shells per sample plot.

Data Analysis

Data analysis uses quantitative analysis of several parameters, namely, Relative Density = Rd, Relative Frequency = RF and Relative Dominance (Relative Dominance = DR) which are used to calculate the Importance Value Index (IVI) , and Standard Dominance Ratio (Summe Diminance Ratio = SDR). Calculation of parameter values uses the following formula (Fanisah et al., 2023)

$$Ad = \frac{The\ total\ population\ of\ A\ weed\ Species}{Total\ area\ of\ all\ sample\ plots} \quad (1)$$

$$Rd = \frac{Abdolute\ density\ A\ Species\ of\ weed}{Total\ absolute\ density\ of\ all\ species}\ x\ 100\ \% \quad (2)$$

$$Af = \frac{Number\ of\ sample\ plots\ containing\ weed\ species}{Number\ of\ all\ sample\ plots} \quad (3)$$

$$Rf = \frac{The\ absolute\ frequency\ of\ a\ weed\ species}{total\ absolute\ frequency\ of\ a\ weed\ species}\ x\ 100\% \quad (4)$$

$$Ad = \frac{The\ populaton\ number\ of\ weed\ speciesis\ multiplied\ by\ the\ dry..}{Total\ area\ of\ all\ sample\ plots} \quad (5)$$

$$RD = \frac{Absolute\ Dominance\ of\ weed\ species}{Total\ absolute\ ominance\ of\ weed\ species}x\ 100\% \quad (6)$$

$$IVI = (Rd) + (Rf) + (RD) \quad (7)$$

$$SDR = \frac{IVI}{3} \quad (8)$$

The important value index (INP) and SDR are then used to analyze and calculate several criteria for vegetation properties and characters. The species similarity index or community coefficient (C), is used to assess the variation and/or similarity of the population number and growth of a weed species in the two communities being compared. The community coefficient is calculated using the following formula (Syahputra et al., 2012).

$$C = \frac{2W}{a+b} \times 100\% \quad (9)$$

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 comparing the population state and number of species of two or more communities. The value of this index is mainly to study the influence of biotic disturbances on the state of vegetation populations. The H' calculation is obtained from the important value or SDR resulting from vegetation analysis, using the following formula (Syahputra et al., 2012).

$$H' = -\sum_{n=1}^{n} \frac{ni}{N}\left(Ln\frac{ni}{N}\right) \quad (10)$$

Where, H' = Shannon-Wiener diversity index; ni = Important value/SDR of a weed species; N = Number of important values/SDR of 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 determining whether each weed species has the same number of individuals evenly distributed in the observation area. Species evenness is maximum when each species population or number of individuals is the same at each observation sample point. The formula for calculating the species evenness index (Suveltri et al., 2014).

$$E = \frac{H'}{H'maks} \quad (11)$$

Where, E = Species evenness index; H' = Shabnon-wiener diversity index; H'maxs = log2 S (S = 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).

$$Ci = \sum_{n=1}^{n}\left(\frac{ni}{N}\right) \quad (12)$$

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 dry biomass data from the dominant weeds obtained in each sample plot was subjected to a regression with the real yield (yield) of the main crop (corn) as the dependent variable with the dry biomass weight and the dominant weed population as the independent variable so that the following regression equation model was obtained:

$$Y = \beta_0 + \beta_{1i} B_i + \beta_{2i} P_i + .. + \beta_{1n}B_n + \beta_{2n}P_n \quad (13)$$

Where, Y is the real yield variable for corn plants, β_0 is a constant, β_1 is the regression coefficient, Bi n is the dry biomass weight of weed species i to the nth species, $P_{i\,n}$ is the population of weeds i to the nth species.

The value of the variable predicting the effect of weeds on corn plants is expressed as Y(DTN) which is the estimated value of Y obtained by entering the observed Bi and Pi values into the regression equation (13). In this article, the Y(DTN) value is referred to as the relative weighted dominance value which is determined by calculating the dry biomass weight value of weeds and/or corn plants multiplied by the population size divided by the total area of the sample plot. The absolute weighted dominance (DTM) and relative (DTN) values of plants and weeds are calculated using the following formula (Ngawit et al., 2023).

$$DTM = \frac{(Biomass\ weight\ to\ n)x\ (Total\ population\ to\ n)}{total\ area\ of\ sample\ plot} \quad (14)$$

$$DTN = \frac{Dominance\ value\ of\ plant\ species\ weight}{Total\ weight\ dominance\ value\ of\ all\ plants} \quad (15)$$

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

$$q = \frac{\beta 1}{\beta o} \quad (16)$$

Where, q = weed competition index; β0 = constant; and β1 = regression coefficient

Furthermore, to predict corn crop yield losses due to weed species competition, an empirical model was applied to the data using the actual yield of weed-free corn as the dependent variable and the weighted relative dominance value of weeds (DTN) as the independent variable (Kropff et al., 1993).

$$YL = \left(DTNt\right)q\left(\sqrt{DTNg}\right) \quad (17)$$

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

Result and Discussion

Diversity, Dominance and Growth of Broadleaf Weeds in Corn

The number of broadleaf weed species found on the land before corn was planted was only 5 species and after corn was planted this number increased to 14 species belonging to 7 families. Most of the 14 species, namely five species belong to the Asteraceae family, four species from the Amaranthaceae family and one species each from the Euphorbiaceae, Commelinaceae, Aizoaceae, Rubiaceae and Solanaceae families (Table 1).

The data in Table 1 shows that the Asteraceae family was found at most, namely 6 species, followed by the Amaranthacea family with 3 species, and the other families with 1 species each. Ettebong et al. (2020), stated that the Asteraceae and Amaranthacea families are plant taxa that have a very large number of species, are cosmopolitan, spread across various habitats with fast and easy reproduction, especially generatively using seeds. Members of the Asteraceae and Amaranthaceae families are able to grow in dry and wetlands and can live throughout open and protected areas in both tropical and sub-tropical areas (Sonya et al., 2018). Apart from being easy to grow and able to dominate a garden area, several weed species from this family are also invasive. Invasive weeds are weeds that are introduced into other ecosystems and will cause economic losses or environmental damage so that they can suppress the growth of plants and other weeds (Firmansyah et al., 2020; Imaniasita et al., 2020).

Evidence of several species from the Asteraceae and Amaranthacea families dominating and being invasive in corn plants is shown in Table 2. From the beginning of growth to the peak period of plant vagetative growth (30 HST – 60 HST), six species were dominant (SDR value > 10.0%) and two species quite dominant (SDR value > 5%) three species from the Amaranthacea family (Amaranthus spinusus, Amaranthus gracilis and Althernanthera philoxeroides), four species from the Asteraceae family (*Synedrella nodiliflora, Ageratum conyzoides, Emilia sonchifolia* and *Eclipta alba*) and only one species from the Euphorbiaceae family, namely Acalypha indica, while the remaining six species are in the non-dominant category. The ability of the eight species of broad-leaved weeds to dominate and invade corn plants is only until the age of 75 HST, then after the plants are 90 HST only three species continue to exist and are dominant, namely *Amaranthus spinusus, Amaranthus gracilis* and *Synedrella nodiliflora*.

So it can be stated that after the plants were 75 HST, 11 species of the 14 species of broad-leaved weeds found were unable to compete and grow on corn plants (Table 2). The cause is thought to be due to the dense canopy of corn leaves so that the intensity of sunlight received by the weed species is very low as a result of which the photosynthesis process is hampered, growth is disrupted and ultimately the weeds die. Rusdi et al. (2019), stated that several species of broad-leaved weeds, such as *P. angulata, A. Indica, C. benghalensis, T. Portulacastrum, B. Alata* and *E. Scaber*, fall into the group of annual, seculent, early maturing weeds and are very sensitive to pressure shade. The presence of several species of this weed in the area of cultivated plants is often used as an indicator of physical and biological soil fertility, for example *Physalis angulata L.* (Pittman et al., 2020).

Table 1. Families and Species of Broad-Leaved Weeds Found on Corn Plants in Dry Land

Familia	Genus	Species name	Indonesian name
Amaranthaceae	Amarantha	Amaranthus spinusus L.	Bayam duri
Amaranthaceae	Amarantha	Amaranthus gracilis Desf.	Bayam hijau
Amaranthaceae	Amarantha	Althernanthera philoxeroides (Mart.) Griseb.	Bayam dempo
Amaranthaceae	Alternanthera	Alternanthera sessilis (*L.*) DC.	Kremah
Asteraceae	Synedrella	Synedrella nodiflora (L.) Gaertn.	Jalantang
Asteraceae	Ageratum	Ageratum conoyzoides L.	Bandotan
Asteraceae	Emilia	Emilia sonchifolia (L.) DC.	TempuhWiyang
Asteraceae	Elephantopus	Elephantopus scaber L.	Tapak liman
Asteraceae	Eclipta	Eclipta alba L.	Orang-aring
Euphorbiaceae	Acalypha	Acalypha indica *L.*	Anting-anting
Commelinaceae	Commelina	Commelina benghalensis L.	Gewor
Aizoaceae	Trianthema	Trianthema portulacastrum L.	Krokot hijau
Rubiaceae	Borreria	Borreria alata (Aubl.) DC.	Rumput setawar
Solanaceae	Physalis	Physalis angulata L.	Ceplukan

Source: Data from research on capacity building at Mataram University 2022

The opposite result can also be seen in the data in Table 2, that several species such as Amaranthus Spinusus, Amaranthus gracilis and Synedrella nodiliflora belong to the group of invasive weeds, are shade tolerant, their seeds have papules which can be carried by the wind over very long distances so that they spread quickly and widely (Hovanes et al., 2023). Apart from having good propagules for reproduction, the root system is also very well developed and strong (Imaniasita et al., 2020). Furthermore, it was also reported by Frank et al. (2020), that with the high seed bank capacity of the three weed species, it turns out that preemergence control using abrasive sand soil cover is more effective than postemergence control even using herbicides. This finding is in accordance with the results of research by Seth et al. (2022) and Dylan et al. (2023), that several weed species from the amaranthaceae family after maturity are susceptible to hericides applied post-emergence.

Also reported by Ngawit et al. (2023), that in drought stress conditions the three invasive weed species are able to survive, adapting by reducing the size of their body organs, shortening their life cycle by speeding up their generative phase, so that they can produce seeds early in very large quantities, if the environment grows. Unripe seeds will be stored as a dormant seed bank in the soil. If soil moisture conditions support weed seeds, they will grow faster than grass weeds (Hao et al., 2021).

The data in Table 3 further confirms the statement above, that the value of the species similarity index (C), in the vegetation communities being compared, shows that the population, growth and dominance of weeds when the corn plants are 30 HST are not significantly different from the state of weed populations when the plants are 30 DAP old. 45 HST and 60 HST. However, it was significantly different from the state of weed populations when the corn plants were 75 HST and 90 HST, with species similarity values (C) greater than 25% and similarity values less than 75% (Table 3).

These results are in accordance with the report by Hilwan et al. (2013), if the species similarity index value is less than 75% then the two communities being compared are significantly different, and if the species similarity value is greater than or equal to 75% then the two communities being compared are not significantly different. When the plants were 30–60 HST, 14 species were found, six species were dominant and two species were moderately dominant. Meanwhile, when the plants were 75 HST, only six species were still growing and when the plants were 90 HST, only three species still existed and dominated.

Table 2. SDR Value (%) for Each Broadleaf Weed Species When the Corn Plant Matures 30, 45, 60, 75 and 90 DAP

Weed species	Plant age (DAP)				
	30	45	60	75	90
Amaranthus spinusus L.	12.17	12.33	15.76	15.17	17.33
Amaranthus gracilis Desf.	14.50	14.53	14.78	15.47	16.55
Synedrella nodiliflora L.	12.24	12.31	16.64	17.38	19.44
Acalypha indica L.	11.29	12.02	15.28	2.07	0.00
Ageratum conyzoides L.	11.28	11.37	5.43	1.46	0.00
Althernanthera philoxeroides (M.) Griseb.	11.13	11.64	5.42	3.14	0.00
Eclipta alba L.	5.26	5.97	1.08	2.06	0.00
Emilia sonchifolia (L.) DC.	3.26	3.11	2.06	2.60	0.00
Alternanthera sessilis (*L.*) DC.	1.52	1.21	1.04	0.00	0.00
Elephantopus scaber L.	1.88	1.08	1.04	0.00	0.00
Commelina benghalensis L.	1.46	1.39	1.06	0.00	0.00
Trianthema portulacastrum L.	1.87	1.07	1.26	0.00	0.00
Borreria alata (Aubl.) DC.	2.32	1.26	1.91	0.00	0.00
Pisalys angulata L.	1.48	1.37	1.00	0.00	0.00
Zea mays L.	8.34	9.34	16.19	40.64	46.67
	100.00	100.00	100.00	100.00	100.00

Source: Data from research on capacity building at Mataram University 2022

There was a significant decline in the number of species, populations and the ability to grow of weeds when the plants were 75 HST - 90 HST, thought to be influenced by changes in environmental conditions such as the corn plant area which was originally open at 30 DAP - 45 HST, then covered by the corn canopy. which gets denser after the plants are 60 HST. Apart from shade pressure, weeds also compete fiercely with corn plants which grow larger to obtain water, nutrients and growing space (Andrew et al., 2022). Furthermore, Abella (2020), reported that soil cover treatment of the canopy and grass weed biomass was able to completely suppress the population of annual broadleaf weeds. However, due to improving structure and increasing water stability of soil aggregates, several species of annual weeds from the broad-leaf group are able to compete with sedge weeds and grasses.

When the corn plants are 30, 45 and 60 HST, the soil is still open, because the corn has not yet grown optimally and the crowns have not yet closed together so that sunlight can still penetrate to the soil surface. According to Suryaningsih et al. (2014), available sunlight really supports the growth of broad-leaf weeds so that they can grow very dominantly on young corn plants. Kresnatita et al. (2018), stated that light is one of the environmental factors that influences weed growth. Low intensity light accompanied by wind stimulation and the sound of classical music has a significant effect on plant leaf growth (Saputri et al., 2023). This was proven after the corn plants were 60 HST, the corn canopy had begun to close together, the population and growth of several weed species began to be suppressed as a result of which some of them were very sporadic, in fact in some sample plots they were no longer found, especially after the plants were 75 and 90 HST. However, three weed species, namely Amaranthus Spinusus, Amaranthus gracilis and Synedrella nodiliflora, continued to exist until the plants were 90 HST, even though they received shade pressure from corn. Broadleaf weeds such as Amaranthus Spinusus, Amaranthus gracilis, Amaranthus tuberculatus, Synedrella nodiliflora, Ageratum conyzoides and Althernanthera philoxeroides are always dominant during the growth of corn plants (Hovanes et al., 2023). Because according to Kerr et al. (2023), some of these weed species are able to spread quickly and evenly throughout the planting area, are drought resistant and tolerant of several types of herbicides and the shade of the corn canopy.

Table 3. Weed Type Similarity Index Values (%) at Each Age Phase of the Compared Corn Plants

Age of corn plants compared	Type similarity index value (%)	Similarity (%)	Difference (%)
30 vs 45	96.700	97.00	3.00 ns*/
30 vs 60	79.885	80.00	20.00 ns
30 vs 75	58.584	59.00	41.00 s
30 vs 90	47.250	47.00	53.00 s
45 vs 60	73.868	74.00	26.00 s
45 vs 75	72.597	73.00	27.00 s
45 vs 90	63.510	49.00	51.00 s
60 vs 75	70.346	70.00	30.00 s
60 vs 90	63.373	63.00	37.00 s
75 vs 90	88.666	89.00	11.00 ns

*/ Differences of more than 25% are significant and similarities of more than 75% are not significant.

The existence of significant differences in the number of species, population and dominance of broad-leaved weeds at each age phase of the corn plant, was apparently in accordance with the results of calculating the diversity, evenness, abundance and species dominance index values. The data in Table 4 shows that the highest diversity index values were obtained when the plants were 30 DAP - 60 HST and the diversity index values decreased further since the plants were 75 DAT - 90 DAP, but were still in the medium range. According to Nanlohy et al. (2024), weed diversity in corn plants which was in the high category was found when the plants were 30 DAP – 60 HST (diversity index value H′ > 2), and decreased with moderate criteria (1 < H′ < 2) after the plants matured. 75 HST - 90 HST.

Table 4. Index Values for Diversity, Evenness, Dominance and Abundance of Broadleaf Weed Species in Each Phase of the Corn Plant's Lifespan

Corn Plant Age (DAP)	H′	E	C_i	D_i
30	2.12	0.81	0.12	90.66
45	2.32	0.90	0.12	81.33
60	2.01	0.76	0.17	83.81
75	1.41	0.54	0.30	57.88
90	1.06	0.40	0.36	53.07

Note: H' = diversity index; E = evenness index; Ci = dominance index; and Di = species abundance index.

The high value of the diversity of broad-leaf weed species obtained was apparently followed by the same trend as the value of the species evenness index (E), which was in the high category when the plants were 30 DAT – 60 HST, namely ranging from 0.762-0.900 (> 0.6). This means that the ability to spread weed species throughout the corn planting area when they are 30 DAT - 60 DAP is high, and this ability decreases when the plants are 75 DAP - 90 DAP, because the evenness index value is less than 0.6 (Table 3). Syahputra et al. (2012), stated that the high diversity and spread of several weed species at the beginning of the growth of corn plants was due to the propagules breeding several weed species which were originally dormant, starting to grow, dominate and spread rapidly due to land processing, fertilization and irrigation and supported by plant spacing fairly wide corn.

The weed dominance index value during plant growth obtained was higher than 0.1, this means that there were several weed species that were dominant during plant growth. Adriadi et al. (2012), states that the dominance index value ranges between 0 - 3. If the dominance index is close to zero, it means that there are almost no dominant individuals and is usually followed by a high species similarity index. Species abundance is considered maximum if all species have the same number of individuals. When the corn plants were 30 DAT – 60 DAP the weed species abundance value was high, 81.33 – 90.67 and when the plants were 75 DAT – 90 DAP the species abundance value was medium with a value of 53.07 – 57.88. So it can be stated that the characteristics of the broadleaf weed population during the growth of corn plants are species diversity and the ability to spread which is high when the plants are 30-60 HST, then decreases to moderate when the plants are 75-90 HST. The dominating ability and abundance of several species is quite high so that three species of broad-leaf weeds were found which always existed and were dominant from the time the corn plants were 30 HST to 90 HST. The three weed species in question are *Amaranthus Spinusus, Amaranthus gracilis* and *Synedrella nodiliflora*.

Competitiveness and Prediction of Corn Yield Losses by Broadleaf Weeds

It seems that the weeds *Amaranthus Spinusus, Amaranthus gracilis, Synedrella nodiliflora, Acalypha indica* and *Althernanthera philoxeroides* have the highest competitiveness and ability to dominate the corn crop area, followed by Eclipta alba and Emilia sonchifolia because of the weighted dominance and competitiveness values (competition index) of the seven these weed species were higher compared to other weed species (Table 5). When the corn plants were 30 HST, the relative weighted dominance (RWD) value of weeds was 85.51% and the RWD value of corn was 14.49%. When the plants were 45 HST, the RWD value of weeds increased to 89.65% and the RWD of corn decreased to 10.35%. When the plants were 60 HST, the RWD value of weeds began to decrease quite a lot, so that it reached 73.86% and this was followed by an increase in the RWD value of corn until it reached 26.14%. When the plants are 75 HST – 90 HST, the RWD value of weeds is very low, only reaching 20.14 – 25.7%, so the RWD value for corn can reach 74.30 – 79.86%. The decreasing relative weighted dominance value of each weed species as the age of the corn plant increases is also accompanied by a decreasing competitiveness index of weeds against the corn plant.

Table 5. Value of Relative Weighted Dominance (RWD) and Competition Index for Broadleaf Weed Species During Planting Corn Aged 30,45,60,75 and 90 of Days After Planting

Weed species	Corn Plant Age (DAP)									
	30		45		60		75		90	
	β	RWD	β	RWD	β	RWD	β	RWD	β	RWD
A. spinusus	0.0086	23.30	0.017	27.07	0.014	28.33	0.004	11.64	0.0003	8.45
A. gracilis	0.0084	16.11	0.018	20.44	0.013	22.76	0.004	6.83	0.0002	6.21
S. nodiliflor	0.0091	15.89	0.015	12.23	0.011	11.02	0.003	7.10	0.0005	5.84
A.indica	0.0063	14.51	0.011	10.30	0.012	10.02	0.002	0.05	0.000	0.00
A.conyzoides	0.0071	5.50	0.012	6.41	0.007	0.93	0.002	0.04	0.000	0.00
A. philoxeroides	0.0068	3.34	0.018	4.81	0.005	0.51	0.001	0.02	0.000	0.00
E. alba	0.0038	4.23	0.009	4.86	0.003	0.09	0.001	0.01	0.000	0.00
E. sonchifolia	0.0034	2.31	0.004	1.42	0.003	0.03	0.001	0.01	0.000	0.00
A. *sessilis*	0.0017	0.01	0.009	0.72	0.001	0.03	0.000	0.00	0.000	0.00
E. scaber	0.0018	0.18	0.008	0.52	0.002	0.04	0.000	0.00	0.000	0.00
C. benghalensis	0.0012	0.02	0.007	0.48	0.001	0.02	0.000	0.00	0.000	0.00
T. portulacastrum	0.0011	0.07	0.005	0.16	0.001	0.03	0.000	0.00	0.000	0.00
B. alata	0.0009	0.01	0.006	0.12	0.002	0.04	0.000	0.00	0.000	0.00
P. angulata	0.0008	0.03	0.007	0.11	0.001	0.01	0.000	0.00	0.000	0.00
Z. mays		14.49		10.35		26.14		74.30		79.86

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

So, the dominant weed species that contributed the highest RWD values were *Amaranthus Spinusus, Amaranthus gracilis* and *Synedrella nodiliflora*, even these three weed species continued to exist and were dominant until the plants were 90 HST. This result is in contrast to 5 other weed species which were only able to survive until the corn plants were 70 HST. According to Jordan et al. (2024), shade from the grass weed canopy can suppress the population and growth of annual weeds. However, annual weeds can suddenly appear with high adaptability and competitive ability, making them more difficult to control both mechanically and using herbicides. Omid et al. (2020), stated that a dense canopy of plant leaves can inhibit the intensity of sunlight from reaching the soil surface so that weeds only receive less than 30% of the intensity of sunlight. Conditions like this cause the growth of annual weeds from the broad-leaf group to be very depressed (Asih et al., 2018). The opposite is true according to DeSimini et al. (2020), annual weed species continue to exist and grow normally so that annual weeds are increasingly suppressed in their growth because they are unable to compete.

The high competitiveness and dominating ability of the weeds, *Amaranthus Spinusus Amaranthus gracilis* and *Synedrella nodiliflora* causes their ability to reduce corn yields higher than other weed species during corn plant growth. The data in Table 6 shows that the real loss of corn plants (yields) at the beginning of their growth, namely at the age of 30 HST, was 17.92%, then increased in line with the increasing age of the plant, namely at the age of 45 HST it was 37.67% and at the age of 60 HST decreased to 22.42%. When the plants were 75 HST, crop yield losses decreased drastically until they reached 3.33%. Meanwhile, when the plants are 90 HST, crop yield loss can be said to not occur because the value is very low, namely only 0.26%. So it can be stated that, as the age of the corn plant increases, the ability of broadleaf weeds to reduce corn yields decreases.

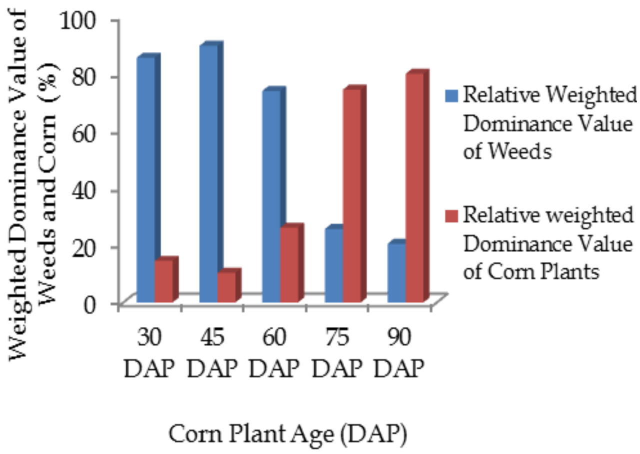

Figure 1. Comparison of weighted weed dominance values with values weighted dominance of corn since the plants are 30 - 90 DAP

Corn crop yield loss due to competition with weeds is influenced by the population size, growth and competitiveness of weeds as reflected in the weighted dominance value and competition index of each weed species. In this regard, in Figure 2, it is clearly seen that at the peak of plant vegetative growth, namely 30 DAP - 45 HST, the *Amaranthus spinosus* weed is able to reduce corn yields by 4.15% - 8.84% and *Amaranthus gracilis* 3.37% - 8.14%. Then after the plants reached 60 HST the ability decreased to 7.45% and 6.20%. When the plants are 75 HST – 90 HST, the ability of the two weed species to reduce crop yields is greatly reduced so that it can be said that the crop yield loss is very low, namely only 0.05% – 1.36%. The same trend also occurred with the weeds *Synedrella nodiliflora* and *Acalypha indica*, that when the plants were 30 HST - 45 HST the loss of crop yield by these two weed species was only 3.63% - 5.23% and 2.39% - 3.53%. Then after the plants were 60 HST the crop yield loss was only 3.65% and 3.80%.

Table 6. Prediction of Corn Yield Loss (YL) Due to Competition with Broadleaf Weeds Since Plants Aged 30, 45, 60, 75 and 90 Days After Planting (DAP)

Weed species	Crop yield loss [YL (%)]				
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Amaranthus Spinusus L	4.15	8.85	7.45	1.37	0.09
Amaranthus gracilis L.	3.37	8.16	6.20	1.05	0.05
Synedrella nodiliflora L.	3.63	5.25	3.65	0.80	0.12
Acalypha indica L.	2.40	3.53	3.79	0.05	0.00
Ageratum conyzoides L.	1.67	3.04	0.67	0.04	0.00
A. philoxeroides (Mart.) Griseb.	1.24	3.95	0.36	0.01	0.00
Eclipta alba L	0.78	1.98	0.09	0.02	0.00
Emilia sonchifolia (L.) DC.	0.52	0.48	0.05	0.00	0.00
Alternanthera *sessilis* (*L.*) DC.	0.02	0.76	0.02	0.00	0.00
Elephantopus scaber L.	0.08	0.58	0.04	0.00	0.00
Commelina benghalensis L.	0.02	0.48	0.01	0.00	0.00
Trianthema portulacastrum L.	0.03	0.20	0.02	0.00	0.00
Borreria alata (Aubl.) DC.	0.01	0.21	0.04	0.00	0.00
Physalis angulata L.	0.01	0.23	0.01	0.00	0.00
Total	17.92	37.67	22.42	3.33	0.26

After the plants are 75 HST – 90 HST, plant yield losses are very low, namely only 0.12% - 0.80%. Meanwhile, on the other hand, the weeds *Ageratum conyzoides, Alternanthera philoxeroides, Emilia sonchifolia, Eclipta alba, Emilia sonchifolia* and *Alternanthera sessilis* are able to reduce corn yields when the plants are 30 HST - 45 HST, 0.476% - 3.95%. After the plants were 60 HST – 90 HST, these six weed species did not cause significant crop yield losses (Figure 2). According to Setiawan et al. (2022), the presence of several weed species does not always harm plants. Gunawar et al. (2023)(2023) also stated the same thing, that the presence of annual weeds, especially from the broad-leaf group, in the initial period of the plant's life cycle and in the period leading up to harvest has very little influence, so broad-leaf weeds that grow during that period do not need to be controlled. Asih et al. (2018), also reported that at the beginning of the growth of corn plants soft and broad-leafed weeds grew early with low competitiveness. So that corn plants make maximum use of available nutrients, water, light, CO2 and growing space. So, in conditions like this, the role of several species of soft and broad-leaf weeds significantly suppresses the growth and population of grass and sedge weeds (Ngawit et al., 2023). However, the three broad-leaf weed species found in corn, namely, *Synedrella nodiliflora, Amaranthus viridis*, and *Amaranthus spinosus*, must be controlled from the beginning of plant growth because they always exist and are dominant during plant growth and have the highest competitiveness and contribution to corn crop yield loss.

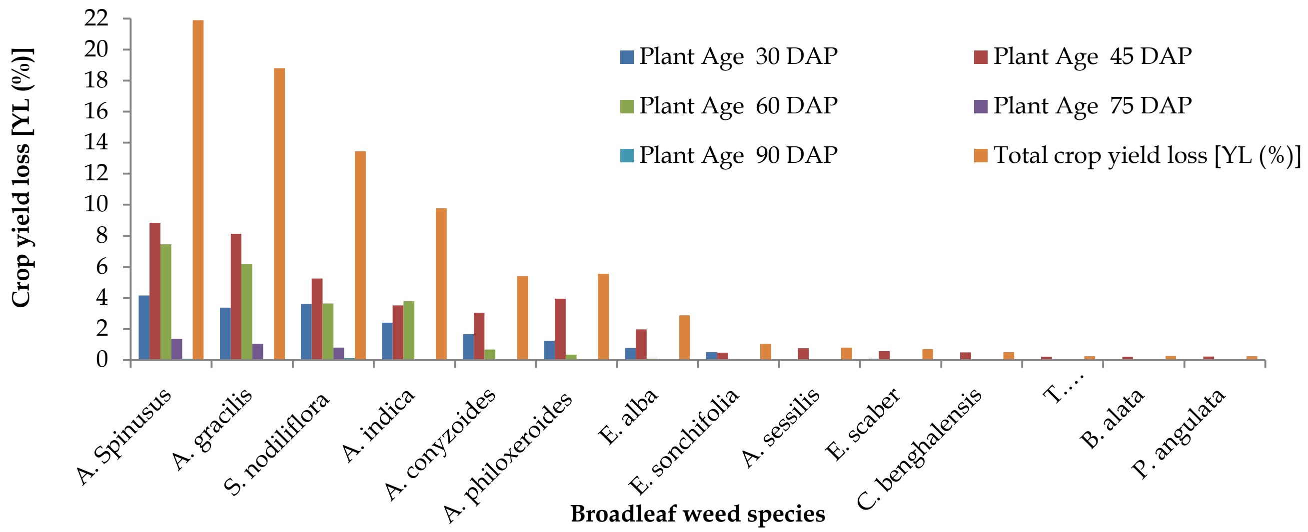

Figure 2. Graph of corn yield loss due to competition with several species of broadleaf weeds since the crop aged 30 HST– 90 HST

Conclusion

Found 14 species of broadleaf weeds with high diversity, distribution, dominance and species abundance indices. The competitiveness and relative weighted dominance of six weed species, namely, *Amaranthus spinusus, Amaranthus gracilis, Synedrella nodiliflora, Acalypha indica, Ageratum conyzoides and Alternanthera philoxeroides*, is higher than other weed species, causing corn yield losses of 5.56% - 21.90%. Therefore, these six weed species must be controlled from the beginning of plant growth because their competitiveness and contribution to corn crop yield losses are high.

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Author Contributions

Conceptualization, I.K.N., I. W. S., I. W. SN.; methodology, I.K.N; validation, I. K. N. and I.W.S.; formal analysis, I. K. N.; investigation, I. W. S., and I. W. SN. ; resources, I. K. N. and I. W.S.; data curation, I. W. SN.: writing—original draft preparation, I. K. N and I. W. S.; writing—review and editing, I. W. SN. and I.W.S. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The author declares that there is no conflict of interest in publishing this scientific article.

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