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Genetic Relationships based on Qualitative Characters Differences of Several Yam bean (*Pachyrhizus erosus*) Lines

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ABSTRACT

Background: The number of yam bean varieties released and circulating in the community is limited, thus there is an opportunity to develop new varieties. This study aims to determine the genetic reationship and differences in qualitative phenotypic characters of breeding lines compared to several other lines.

Methods: The research was conducted in Kutasari Village, Baturaden District, Banyumas Regency, Central Java Province, from February to June 2023. The study involved six lines, repeated four times using a randomized block design. The six lines of yam bean under treatment included Banyumas Line, Binjai Line, Kediri Line, Madura Line, Padang Line and Line X. Qualitative data were processed descriptively and genetic reationship tests were conducted using a dendrogram.

Result: The results showed that the breeding yam bean (Line X) had different qualitative characters in the parameters of color (stem, leaf, flower, seed and tuber) and seed shape. Line X showed a similarity with Padang Variety of 34.27%, Madura and Kediri lines of 21.03%, Binjai line of 13.79% and Banyumas line of 0%. Line X had similar qualitative phenotypic characters in the parameters of shape (stem, leaf, leaf tip and leaf edge) and leaf surface. Yam bean Line X has the potential to become a new variety.

Key words: Breeding, Character, Line, Qualitative, Yam bean.

INTRODUCTION

Yam bean serves strategically as food, medicine and cosmetics (Ningsih *et al.*, 2019). Market demand for yam bean is substantial (Pudyastuti *et al.*, 2022), yet its production is seasonal, failing to meet off-season needs. Additionally, its productivity as a functional food remains low. Productivity is influenced by variety and growing agroecosystem. The number of released yam bean varieties is minimal, with only one released variety, Kota Padang. Farmers often use uncertified seeds, leading to inconsistent seed development across regions, presenting a challenge and an opportunity for breeding new, superior yam bean lines (Ningsih *et al.*, 2019). Utilizing genetic resources/germplasm for selection is vital in plant breeding (Fransisko and Bainamus, 2020).

The goal of plant breeding is to obtain genetically superior traits preferred by consumers. The success of breeding superior varieties depends on genetic diversity reflected in qualitative phenotypic characteristics. Breeding can involve collecting germplasm, crossing and mutating. The resulting lines are characterized and analyzed for similarities to facilitate evaluation. In 2019, a yam bean line, Line X, was purified through selection. The characteristics of Line X need comparison with existing varieties to identify distinguishing features. Conventional breeding can develop new lines. This requires phenotypic and genotypic diversity information (Rihadi *et al.*, 2021). Potential lines are obtained through selection, which focuses on permanent traits from a population to define variety identity (Rihadi *et al.*, 2021). Genetic variation is observable through morphological traits.

Similarity assessments of lines/varieties are based on morphological and phenotypic characteristics (Akinyosoye, 2022; Hamdi *et al.*, 2024; Noviana *et al.*, 2023) and genetics (Nugraha *et al.*, 2017). Similarity is evaluated based on genetic and phenotypic relationships (Shikha and Narayan, 2020). Genetic diversity indicates the genetic distance of a line from its parent and dendrogram results show clusters due to geographic differences (Sari *et al.*, 2017). Cluster analysis determines relationships, with greater genetic distance offering more opportunities for genetic purification (Nugraha *et al.*, 2017). Morphological character-based cluster analysis helps obtain genetic resources for new varieties. Krisnawati *et al.* (2018) grouped 73 yam bean varieties into three clusters. Cluster analysis groups lines based on morphological similarities. Developing new varieties/lines can yield more attractive and superior seed products (Olomitutu *et al.*, 2022). These morphological characters were shown to effectively differentiate genotypes and were recommended as

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selection indices for breeding programs aimed at improving chickpea adaptability and yield potential (Yadav *et al.*, 2025). The utility of morphological traits in revealing genetic diversity and guiding parental selection for the development of high-yielding *Phaseolus vulgaris* L. varieties (Hussain *et al.*, 2025). This study aims to identify differences in qualitative phenotypic characteristics and relatedness among bred yam bean lines and local lines, hoping that newly bred lines could potentially become new varieties.

MATERIALS AND METHODS

The research was conducted in Kutasari Village, Baturraden District, Banyumas Regency, Central Java, from February to June 2023. Randomized Block Design (RBD) with four replicates was used. Treatments included six yam bean lines: Banyumas Line, Binjai Line, Kediri Line, Madura Line, Padang Variety and Line X.

The experiment began with creating beds measuring 1.25 m×2.0 m. The beds were prepared and fertilized with organic manure. Seeds were soaked for 12 hours before planting at a depth of 2.5 cm with a spacing of 25 cm×30 cm, planting 20 plants per bed. Fertilization with NPK 16-16-16 was applied at 30 and 70 days after planting (DAP) at a rate of 3 g/plant using a tugal system. Observations were made on five randomly selected plants per plot, focusing on qualitative traits of plant type, stem, leaf, flower, seed and tuber. Morphological observation as detailed in Table 1 (Tjitrosoepomo, 2009).

The qualitative phenotypic data were analyzed descriptively and through cluster analysis using OriginPro software, with results presented as a dendrogram. Quantitative data on productivity traits were analyzed using the 5% Honestly Significant Difference (HSD) test.

RESULTS AND DISCUSSION

Qualitative phenotypic characteristics of yam bean were measured across parameters including plant growth type, stem, leaf, flower, seed and tuber. The study compared the characteristics of the bred line (Line X) with other lines. Table 2 presents the qualitative phenotypic characteristics of Line X and other lines. Morphological diversity is one trait that can be utilized to enhance plant superiority (Abdulkareem *et al.*, 2015).

The bred yam bean line (Line X) has a climbing growth type, similar to the Banyumas, Kediri, Madura lines and the Kota Padang variety, but differs from the Binjai line, which has an upright growth type. The growth type is largely influenced by genetic factors. Line X has the same stem shape (round) as the other lines. The stem color of Line X is the same as the Banyumas line but differs from the other lines. The stem color of Line X and Banyumas is RHS Greyed Purple-N186-B, while the stem color of Binjai, Kediri and Madura lines is RHS Yellow Green Group-144-A and Padang is RHS Greyed Purple-N186-A (Table 2). The stem appearance of Line X is similar to that of Banyumas. Differences in stem color are due to pigment changes resulting from chlorophyll expression mutation, as seen in African yam beans (Abdulkareem *et al.*, 2015).

The leaf characteristics of Line X are similar to other lines, particularly in leaf shape (diamond), leaf tip (pointed), leaf edge (smooth) and leaf surface (hairy). Leaf shape is an essential distinguishing character in yam beans (Karuniawan, 2006). The leaf color of Line X is similar to Banyumas (RHS 147-A) but differs from Binjai, Kediri, Madura and Padang lines (RHS NN137-A). The petiole color of Line X is the same as Kota Padang (RHS 147-A) but differs from Banyumas (RHS 202-A), Binjai, Madura (RHS 144-A) and Kediri (RHS 146-A) lines. Differences in leaf color are due to pigment changes in chlorophyll, which alter qualitative traits (Abdulkareem *et al.*, 2015).

The flower petal shape of Line X is the same as Banyumas, Kediri, Madura and Padang lines (moderately raised) but differs from Binjai (highly raised). The flower petal color of Line X is RHS Violet Blue Group-91-A, distinct from all other yam bean lines. The sepal color of Line X is the same as Banyumas and Padang (RHS N199-B) but differs from Binjai, Kediri and Madura lines. The stigma and stamen color of Line X match Madura (RHS 11-A) but differ from Banyumas, Binjai, Kediri and Padang lines. The style color of Line X is the same as Banyumas (RHS 157-D) but differs from Binjai, Kediri, Madura and Padang lines. These color changes are due to protein content variations from physiological processes (Hayati *et al.*, 2022) and chlorophyll pigment formation (Zakiyah *et al.*, 2018). Chlorophyll is the green pigment in plants, influenced by environmental factors such as light, temperature and humidity (Zakiyah *et al.*, 2018).

The tuber shape of Line X is the same as other yam bean lines (top-shaped). The skin color of Line X is the same as Binjai (RHS 163-D) but differs from Banyumas, Kediri, Madura and Padang lines. The flesh color of Line X matches Madura and Padang (RHS 155-D) but differs from Banyumas, Binjai and Kediri lines. Tuber color is determined by the content of natural pigments like carotenoids, tannins, anthocyanins and flavonoids. Changes in tuber color are influenced by flavonoid components, which can impart color to leaves, flowers, fruits and tubers (Priska *et al.*, 2018). The seed shape of Line X is the same as Padang (elongated round) but differs from Banyumas, Binjai, Kediri and Madura lines. The seed color of Line X is the same as Kediri and Madura (RHS 165-B) but differs from Banyumas, Binjai and Padang lines.

The relationship test was conducted using morphological (phenotypic) characterization data scored with MS Excel and organized into a dendrogram using the UPGMA (Unweighted Pair Group Method with Arithmetic Averages). The dendrogram was based on various parameters including plant type, stem color, leaf color, petiole color, flower petal shape, flower petal color, sepal color, stigma color, stamen color, style color, tuber skin color,

Table 1: Parameters and methods for observing qualitative characteristics of jicama.

Parameter	Observation method
Plant type	Plant type is visually observed for each part of the plant at 45 days after planting (DAP). Criteria: Climbing (1), Upright (3).
Stem shape	Stem shape is observed based on the roundness of the stem diameter at 105 DAP. Criteria: Round (1), Angular (3), Flat (5), Cylindrical (7)
Stem color	Stem color is measured using the RHS Colour Chart at 45 DAP.
Leaf shape	Leaf shape is observed on fully opened leaves at 45 DAP. Criteria: Ovate (1), Triangular (3), Delta (5), Rhomboid (7).
Leaf color	Leaf color is measured with the RHS Colour Chart on green leaves at 45 DAP.
Petiole color	Petiole color is observed using the RHS Colour Chart on green leaves at 45 DAP.
Leaf tip	Leaf tip is observed on fully opened leaves at 45 DAP. Criteria: Pointed (1), Tapering (3), Blunt (5), Rounded (7), Notched (9), Split (11), Spiny (13).
Leaf edge	Leaf edge is observed on fully opened leaves. Criteria: Smooth (1), Serrated (3).
Leaf surface	Leaf surface is observed on fully opened leaves. Criteria: Smooth (1), Glabrous (3), Rough (5), Wrinkled (7), Warty (9), Hairy (11), Densely Hairy (13), Coarse Hairy (15), Scaly (17).
Corolla shape	Corolla shape is observed after the flower is fully opened and fresh when 30% of the population is in bloom. Criteria: Very Elevated (1), Moderately Elevated (3), Flat (5), Moderately Curved (7), Very Curved (9).
Calyx color	Flower calyx color is measured using the RHS Colour Chart after the flower is fully opened and fresh when 30% of the population is in bloom.
Corolla color	corolla color is measured using the RHS Colour Chart after the flower is fully opened and fresh when 30% of the population is in bloom.
Stigma color	Stigma color is measured using the RHS Colour Chart after the flower is fully opened and fresh when 30% of the population is in bloom.
Style color	Style color is measured using the RHS Colour Chart after the flower is fully opened and fresh when 30% of the population is in bloom.
Stamen color	Stamen color is measured using the RHS Colour Chart after the flower is fully opened and fresh when 30% of the population is in bloom.
Seed shape	Seed shape is observed on mature, dry and ready-to-plant seeds visually. Criteria: Round (1), Elongated Round (3), Square (5).
Seed color	Seed color is measured using the RHS Colour Chart on mature, dry and ready-to-plant seeds visually.
Tuber shape	Tuber shape per sample is observed after tuber harvest at 3.5 months after planting. Criteria: Top-shaped (1), Spear-shaped (3).
Tuber skin color	Tuber skin color is measured using the RHS Colour Chart after harvesting the tubers at 3.5 months after planting.
Tuber flesh color	Tuber flesh color is measured using the RHS Colour Chart after harvesting the tubers at 3.5 months after planting.

tuber flesh color, seed shape and seed color. The scoring results for each parameter of the yam bean lines are presented in Table 3.

Cluster analysis utilizing morphology parameters revealed distinct population groupings, reflecting inherent genetic divergence. These results confirm that morphological characteristics serve not only as valuable tools for taxonomic classification but also provide critical insights for plant breeding programs, particularly during initial selection and domestication phases targeting economically important traits in neem (Swati *et al.*, 2025).

Table 2: Observation results of qualitative traits in several yam bean lines.

Parameter	Lines					
	Banyumas	Binjai	Kediri	Madura	Padang	X
Plant type	Climbing	Upright	Climbing	Climbing	Climbing	Climbing
Stem shape	Round	Round	Round	Round	Round	Round
Stem color	N186-B	144-A	144-A	144-A	N186-A	N186-B
Leaf shape	Diamond shape	Diamond shape	Diamond shape	Diamond shape	Diamond shape	Diamond shape
Leaf color	147-A	NN137-A	NN137-A	NN137-A	NN137-A	147-A
Petiole color	202-A	144-A	146-A	144-A	147-A	147-A
Leaf tip	Point	Point	Point	Point	Point	Point
Leaf edge	Flat	Flat	Flat	Flat	Flat	Flat
Leaf surface	Hairy	Hairy	Hairy	Hairy	Hairy	Hairy
Corolla shape	Medium raised	Highly raised	Medium raised	Medium raised	Medium raised	Medium raised
Corolla color	90-C	91-B	92-A	92-A	92-A	91-A
Calyx color	N199-B	152-B	200-D	N199-A	N199-B	N199-B
Stigma color	13-B	12-A	12-A	11-A	10-B	11-A
Stamen color	13-B	12-A	12-A	11-A	10-B	11-A
Style color	157-D	157-C	157-A	157-B	157-C	157-D
Tuber shape	Spindle-shaped	Spindle-shaped	Spindle-shaped	Spindle-shaped	Spindle-shaped	Spindle-shaped
Tuber skin Color	161-C	163-D	161-D	161-C	161-C	163-D
Tuber flesh Color	155-B	155-B	155-B	155-D	155-D	155-D
Seed shape	Round	Square	Round	Round	Elongated round	Elongated round
Seed color	N199-D	164-B	165-B	165-B	165-A	165-B

Table 3: Scoring of qualitative characteristics of several yam bean lines.

Parameter	Galur					
	Banyumas	Binjai	Kediri	Madura	Padang	X Line
Plant type	1	3	1	1	1	1
Stem shape	1	1	1	1	1	1
Stem color	5	1	1	1	3	5
Petiole color	7	1	3	1	5	5
Leaf shape	7	7	7	7	7	7
Leaf color intensity	3	1	1	1	1	3
Leaf tip	1	1	1	1	1	1
Leaf edge	1	1	1	1	1	1
Leaf surface	11	11	11	11	11	11
Corolla shape	3	1	3	3	3	3
Calyx color	5	1	7	3	5	5
Corolla color	1	5	7	7	7	3
Style color	7	5	1	3	5	7
Stigma color	9	7	7	5	3	5
Stamen color	9	7	7	5	3	5
Tuber shape	1	1	1	1	1	1
Tuber skin color	1	5	3	1	1	5
Tuber flesh color	1	1	1	3	3	3
Seed shape	1	5	1	1	3	3
Seed color	7	1	5	5	3	5

The extent of genetic diversity among parental lines influences the number of clusters formed during breeding programs (Chandra *et al.*, 2024). The relatedness among the yam bean lines was measured based on the similarity of the observed parameters. The six observed lines exhibited identical similarities in stem shape, leaf shape, leaf tip, leaf edge, leaf surface and tuber shape. Cluster analysis of the six lines revealed two major clusters: Cluster 1 consisting of the Banyumas line and Cluster 2 consisting of the Binjai, Kediri, Madura, Padang and X lines (Fig 1). The Banyumas line had 0% similarity with the lines in Cluster 2. Cluster 2 was further divided into three subgroups: Subgroup 1 (Binjai), Subgroup 2 (Madura and Kediri) and Subgroup 3 (Padang and X). The Binjai line showed 13.79% similarity with Subgroup 2 and 21.03% similarity with Subgroup 3. Line X showed 34.27% similarity with the Padang line.

The assessment of a bred line can be evaluated through changes in qualitative phenotypic characteristics, which differentiate it from other lines. The changes in plant characteristics can be measured by morphological appearance. The evaluation of genotypic changes using morphological parameters is crucial (Nusifera and Kurniawan, 2016; Silva *et al.*, 2016). Morphological parameters, including stem, leaf, flower, seed and tuber, are vital for determining the yield of yam beans (Aina *et al.*, 2021). Selecting lines/varieties in yam bean cultivation is challenging due to the long lifespan of the plants (Aina *et al.*, 2021). Each line/accession has specific morphological characteristics (Baiyeri *et al.*, 2022). Environmental conditions, such as climate and soil, influence changes in morphological characteristics. According to Sebayang *et al.* (2023), growth environments have shaped different morphological characteristics in cassava.

Table 4: Productivity data per hectare (Kg/Ha).

Lines	Productivity (Kg/Ha)
Banyumas	920,89bc
Binjai	1.068,00ab
Kediri	808,00cd
Madura	732,00d
Padang	656,00d
X	1.214,23a
BNJ 5%	

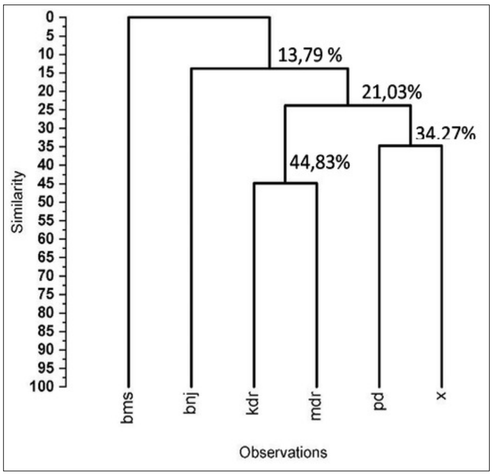

Fig 1: Dendrogram of genetic relationship testing among lines.

This study revealed that the breeding of the yam bean hopeful line resulted in Line X, which exhibited various differences in qualitative characteristics. The main differences between Line X and the comparison lines/varieties lay in the growth type, color of various parts (stem, leaf, flower, seed and tuber). Yam bean growth types are classified into two categories: 1) upright and 2) climbing. Line X has a climbing growth type, unlike the Binjai line, which has an upright growth type. This growth type is influenced by genetic factors and is not affected by environmental conditions such as climate and soil.

The stem, which translocates nutrients to various plant parts, shows differences in Line X compared to the Binjai, Madura, Kediri and Padang lines. Stem color differences are influenced by chlorophyll pigment content. According to Nurchayati *et al.* (2019), color differences are due to variations in pigment content within the plant tissue. Leaf color is a distinguishing feature of yam bean lines. Line X differs in leaf color from all comparison lines due to the presence of chlorophyll. Danniswari *et al.* (2019) noted that leaf color changes are due to chlorophyll content and nutrient supply to the leaves. Ai and Banyo (2011) mentioned that pigment formation in plants is influenced by genetic factors.

Seed characteristics, particularly color and shape, show notable differences. Line X has different seed colors compared to the Banyumas and Padang lines and different seed shapes compared to the Banyumas, Binjai and Kediri lines. Seed color changes are influenced by soil nutrient support (Ikhajiagbe and Kwesi Mensah, 2012).

Line X shows differences in tuber characteristics compared to the Banyumas, Kediri, Madura and Padang lines. Tuber color changes are influenced by mineral content. Yam bean tubers contain iron, calcium and protein, affecting tuber appearance (Ibirinde *et al.*, 2019). Additionally, yam beans contain flavonoids and phenolic acids (George *et al.*, 2020).

Qualitative character analysis serves as a reference for determining plant relatedness. Morphological identification, observing the plant type, leaf, stem, flower, tuber and seed, is used to determine phenotypic characteristics (Hartati *et al.*, 2015). Morphological characterization involves observing qualitative plant characteristics. Phenotypes are used to detect morphological plant characteristics.

The distance in relatedness among species is influenced by differences in morphological characteristics, one of which is qualitative traits (Kinasih *et al.*, 2017), describing phenotypic characteristics. This study shows that yam bean lines exhibit similarities in stem shape, leaf shape, leaf tip, leaf edge, leaf surface and tuber shape. The dendrogram is based on different parameters: plant type, stem color, leaf color, petiole color, flower petal shape, flower petal color, sepal color, stigma color, stamen color, style color, tuber skin color, tuber flesh color, seed shape and seed color. The Kediri and Madura lines exhibit 44.83% similarity across all qualitative parameters except petiole color, sepal color, style color, stigma color, stamen color, tuber skin color and tuber flesh color.

The Padang and Line X exhibit 34.27% similarity across all qualitative parameters except stem color, leaf color, flower petal color, style color, stigma color, stamen color, seed color and tuber skin color. The Binjai line shows 13.79% similarity with differences in plant type, stem color, petiole color, leaf color, flower petal shape, sepal color, flower petal color, style color, stigma color, stamen color, seed shape, seed color, tuber skin color and tuber flesh color, but is characterized by an upright plant type and highly raised flower petal shape. Banyumas line exhibits 0% similarity with other lines. The Banyumas line shows differences in petiole color, stigma color, stamen color and seed color, with the most distinct scoring from other lines. Line X has a distant relatedness to all lines. The similarity indicates that phenotypic character similarity among yam bean lines genetically suggests a close relationship. According to Purnomo *et al.* (2017), a similarity level of ≥ 70% indicates a close genetic relationship among lines.

Quantitative data on productivity traits were analyzed using Honestly Significant Difference (HSD) test. The analysis for the productivity variable indicate that Line X has the highest productivity compared to the Banyumas, Kediri, Madura and Padang lines (Table 4). However, the productivity of Line X is not significantly different from that of the Binjai line. Productivity is one of the key criteria in plant breeding for developing superior varieties with improved yield and adaptation to specific environments. Knowing the productivity of a line can facilitate the selection of high-yielding lines for further development as elite varieties.

CONCLUSION

Line X shows the highest similarity with the Padang variety, followed by the Madura and Kediri lines, Binjai and the Banyumas line. The differences in qualitative characteristics between Line X and Binjai encompass 12 parameters (60%), Kediri 11 parameters (55%), Madura 9 parameters (45%), Banyumas 7 parameters (35%) and the Padang variety 6 parameters (30%). Line X has distinctive qualitative characteristics, including the flower petal color RHS Violet Blue Group-91-A and the tuber skin color RHS 163-D. The results of the 5% HSD analysis for the productivity variable indicate that Line X has the highest productivity compared to the Banyumas, Kediri, Madura and Padang lines. However, the productivity of Line X is not significantly different from that of the Binjai line.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

There are no animal procedures for experiments during data collection of this study.

Conflict of interest

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