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Review on the Importance and Breeding History of Spider Plant (*Gynandropsisgynandra (L.) Briq*.)

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Abstract: Climate change is the most dangerous and existing in every of the world including where whether suitable for live or not. Before, a century the headache of climate change impact is very low and focused on industrialization. As economy and civilization rising up, the population number double, tripled or dramatically increased in developing countries with less family planning technology. The fuel of climate change is over population, less improved conservation technology and less climate smart legacy. Several developed countries reached adaptation strategy than mitigation, while in developing countries challenging with mitigation, and even awareness creation about the climate change. Thus, orphan crops conservation and cultivation practices plays significant role in to overcome the challenge may happened due to climate change such as genetic erosion adaptation problems and technology development. Spider plant is very smart crop majorly found in different African countries of orphan species. It is used for several problems and exceptional characters. It is uses as sources of food, income, medicinal values, and more adapted at low moisture areas by escaping with methods of short life span and high water use efficiency. However, the improvements activities through breeding and agronomic practices still very on infant stage. Therefore, this review gives some importance of the crop, its history of improvements and future opportunity to improve the spider plant.

Keywords: Spider Plant, Importance, Breeding History

1. Introduction

The Spider plant (*Gynandropsisgynandra (L.)*) is an orphan leafy vegetable and has been cultivated in different African, Asian and American countries [40, 34]. Although less information to describe in exact origin, but it has been believed originated in Africa and Asia [30, 78]. Wiathaka [78] reported that it was widely dispersed and less unification studies, and has different English names such as spider plant, cat's whiskers, spider flower, and bastard mustard from local nomenclatures across the cultivating countries.

The spider plant has been belongs to Cleomaceae family which have more than 200 species [4]. Onyango [54] reported that 50 species of spider plant were native in Africa which spineless and delicious for food. The spider plant has been diploid chromosome number of 2n = 18, 20, 30, 32, 34, 36 were reported, however, it has been diploid with a chromosome number of 2*n* = 34 was recently investigated [51].

The spider plant is erected and often semi erected herbaceous growth and some of it is genotype freely growth up to 1.50m under optimum condition [59]. The plant has different stem color, branches alternate and palmate compound leaves which are pinnately dissected and sessile [78]. It has been produced andromonoecy flowers within four weeks after germination while it may take longer weeks in the field of transplanted.

The spider plant is categorized under C_4 photosynthetic pathway, which widely adapted to high temperature and variable agro climate conditions [7]. It is grown in altitudes of 0 - 2400m, and preferred clay loam soils which well-drained with a pH of 5.5–7.0 and temperature between 18-25°C [78].

The spider plant is a vital leafy vegetables next to Amaranthus, Cowpea and African nightshades [51]. It has plenty of proteins, micro-nutrients, beneficial health compounds, source of food security and income generation [56, 32]. Onyango *et al.* [55] reported that the spider plant to be grown for home consumption about 57% and income generation 43%. In addition, It has been provided substantial medicinal values to the people e.g. used to stimulate milk production with mothers, treat anemia, rubefacient and vesicant, rheumatism, diarrhea, and to treat chest pain [46]. Moreover, spider plant was used as biological control of insect pest namely diamondback, moth larvae and flower trips [10, 67]. Hence, it has been provided net product and potential to support all users.

The spider plant production has been increased in different African countries. In Kenya, 2013 annual production was better 10.7% Mt than 2012 and area of production increased from 2256 ha to 2336ha [27]. Omondi *et al* [52] listed out African countries' underproduction of spider plant namely, Kenya, Uganda, Zimbabwe, Zambia, Burkina-Faso, Ghana, South Africa, Malawi, Botswana, Cameroon, Namibia, Tanzania, and Benin widely cultivated in the communities. Therefore, it contributes to regional diets, ability to being in climate change, and may already be integrated into existing production systems, yet there is little investment to improve their productivity or quality [73].

More than 542 accessions of spider plant genotypes were collected and ex-situ conserved at world Vegetable Center, different African countries and National Plant Germplasm center of USA [73]. In order to improve the species, several studies of characterization carried out showed the existence of great genetic diversity [38]. Availability of genetic diversity in the accessions with slight attention firmed the hope of improvements and initiated the stakeholders to plant breeding. However, limited information on developed varieties, improvement, and knowledge of breeding [44].

Considerable genetic variation existed between traits of spider plant accessions. This indicated that it has been offering large prospects to develop improved varieties [38]. However, breeding status is still minutes and less in information in the genomic area. Similarly, there is not yet information reported on hybrid or heterosis advance [73].

Hybrid variety development is highly based on genomic information generated in the species diversity. Spider plant hybrid variety development may important and exist with desired characteristics. It should be considering the desirable characters prefer or suggested by the users (farmers, retailers, and consumers).

Developing improved varieties with desirable characteristics determined by parental line genotype of its genome information. Genetic evaluation of parental line after the selection is a crucial point to get the desirable characteristics of both parents. It is important to understand insight about the genetic architecture of target traits from the start of a breeding program [73].

Developing appropriate information which included existed gap based on the crop characters was required. Knowledge of combining ability of the parents is an important strategy for hybrid variety development. Mating design is the primary important tool to produce heterosis and its information. However, its influenced by the objective of the breeder and the nature of crop reproductive organ and the way of pollination. North Carolina Mating Design is advanced in use to breed plant of different floral structure and recommended for which may have more than one floral structures. In addition, it is also important for reducing the number of crosses and constitute large number of parental lines divided independent set of male and female groups.

General combining ability (GCA), specific combining ability (SCA), and the type of gene action involved (additive, dominant, and epistatic), the magnitude of genetic and phenotypic variances, and the heritability of key traits can influence the process of improved cultivars were investigated in the study. Therefore, this study was basically tried to generate such important genetic information using appropriate factorial North Carolina II mating design. Therefore the objective of this review is to the presented information on the gene action and combining ability in spider plant for further improvement promises along several production areas for further study and give direction.

2. Origin, Botanical and Morphological Description of Spider Plant

Spiderplant (*Gynandropsisgynandra (L.) Briq.*) is one of an important endogenous African leafy vegetable which grown predominantly in Africa, Asia and somehow in America. The exact origin is not well known while it believed to be originated from tropical Africa and Asian countries [30, 78, 71]. The species is native to different African countries namely; South Africa, Western Africa, Central Africa, Eastern Africa and southeast Asia [14]. It has different common names such as spider flower plant, African spider plant or cats' whiskers and African cabbage.

Both *Gynandropsisgynandra* and *Cleome gynandra*are widely used [10]. International Plant genetic resource Institute (IPGRI) and taxonomist agreed on the later in recent publication [68]. Similarly, different reports regarding the number of chromosomes. Koshy and Mathew [41] report $2n$=34, while Raghavan and Kamble [64] reported that $2n$=20 chromosomes. However, diploid (2n=34) chromosomal numbers more explained assured the nature of the plant [50]. Polyploidy has also been shown to occurred [15].

The spider plant is a herbaceous erect annual plant which grow up to 1.5m tall, branched, with a long taproot and few secondary roots, and stem densely glandular structures [58]. It produces an alternate, palmate compound with 3 to 7 leaflets, petiole 2–10 cm long, acute or acuminate at apex, margins finely toothed, sparsely to distinctly hairy leaves and efflorescence long up to 30cm [79].

The spider plant is short life cycle less than 4 months and produces flowers between 3-4 weeks after transplanting, means 6-8 weeks after planting [10]. The species has been propagated though seeds. The efflorescence produce is a terminal raceme which bears many flowers consisted of staminate with the a residual devoid ovary and hermaphrodite with the functional ovary and stamen floral structure [73]. Furthermore, 70% of staminate and 30% of hermaphrodite flowers likely occurred in the population and it has unique floral structure from exogenous and endogenous vegetables [81]. It follows both self and cross-pollinated [33].

Spider plant produces andromonoecy flower types. Andromonoecy is a sex expression in which both hermaphrodite flowers and male flowers are produced in an individual plant [81]. It is polygamodioecious, which representing functionally staminate short gynoecium floral type and functionally hermaphrodite medium and long gynoecium floral types [65]. According to Zohoungbogbo *et al.* [81] reported that it is an andromonoecious plant with three categories of flowers: functional staminate with short gynoecium, functional hermaphrodite with medium gynoecium, and functional hermaphrodite with long gynoecium.

Ecology and Production Status of Spider Plant

The Spider plant is adapted to a wide range of environmental conditions. It grows from sea level up to 2400 *m a.s.l*, and optimum growth in temperatures between 18 to 25°C, while stunted under shade [79]. The species is a C4 plant and hence combines efficient water utilization with high photosynthetic capacity at optimum temperatures [31]. The species tolerates some drought conditions, however a water stress have been triggered hasten maturity and senescence of the plant [10].

The species does not appear to be sensitive to day length, although leaves exhibit strong rhythmic circadian movements which follow the direction of the sun [10]. It requires soils with high organic matter content, with adequate mineral reserves. It is widely grown on a range of soils, which are deep and well-drained, with a pH range of 5.5-7.0 and soil types range from sandy loam to clay loams [10].

The Spider plant will be known among important traditional leafy vegetables widely used in Africa [68]. Its production is increasing from year to year due to population increases, adapt to harsh environments and it is short life span which compatible with the short rainy season. The African countries that produce spider plant are Kenya, Uganda, Tanzania, South Africa, Malawi, Botswana, Cameroon, Namibia, Zimbabwe, Zambia, Swaziland, Benin and Ghana [14]. For instance, in Kenya, due to increased demand of user, production increased from 19,428MT in 2012 to 21,507 MT in 2013 and in a similar case, area of production increases from 2256 ha to 2336ha [27].

3. Importance of Spider Plants

Orphan crops have potential to reduce stunting, malnutrition, and hidden hunger through nutritious, economic, and resilient agri-food system in sub-Saharan Africa which harbors a large portion of the severely malnourished population on the world [29]. Generally, the spider plant accounted an immeasurable role in food security, medicinal values and often income generation in producing communities and biological control. Further, each of the listed important described below.

3.1. Nutritious Value

Spider plant has been playing an important portion in alleviating hunger and malnutrition in African and SSA countries and important sources of macro and micro mineral nutrients [67]. The edible parts include leaves, shoots and often the flowers, which are boiled and eaten as an herb, tasty relish, stew or side dish [58]. It has been used as a fresh or dried. Fresh leaves are used as ingredients in other mash foods, and the dried leaves are ground and incorporated in weaning foods [28].

The spider plant used as sources of nutrients such as protein, vitamins and superior in micronutrient contents than exotic leafy vegetables [58]. For instance, it is high sources of vitamins A and C [79]. Similarly, minerals such as calcium, magnesium, zinc and iron content in spider plant were higher than normal recommended for adult daily allowances [14]. Chweya *et al.* [11] reported that the Crude Protein content of 3.1-7.7% has been reported in spider plant. It has also an important source of beta-carotene and Vitamin c levels where 6.7-18.9 mg/100 g and 127- 484 mg/100 g respectively [45]. In the leaf of spider plant, calcium and magnesium content of 213-434 mg/100 g and 86 mg/100 g were obtained and were relatively high [11, 58].

3.2. Medicinal Purposes

Substantial cultural important medicinal orphan crops practiced such as spider plant. Indigenous knowledge owned by rural peoples knows that it has several medicinal uses [58]. The concoction crushed spider plant leaves is used to cure scurvy [58, 28]. It local famer’s, leaves are boiled and marinated in sour milk for 2-3 days and eaten as a nutritious meal, which is believed to improve eyesight, provide energy and cure marasmus [9]. It is recommended meal for pregnant and lactating women and reduces dizzy spells in pregnant women [40]. Similarly, Kokwaro [40] reported that regular consumption of sap from pounded leaves eases childbirth women.

It is known to have a variety of ethnomedical uses such as treatment of malaria, piles, rheumatism and anti-tumor activity [6]. In addition, the methanol extract of spider plant possesses good total antioxidant potential [47]. Sap from leaves may be used as an analgesic, particularly for headaches, pounded young leaves squeezed into ears, nostrils, and eyes to treat epileptic fits and earache. In addition, decoction or infusion of boiled leaves and/or roots is administered to treat stomach-ache and constipation, treat conjunctivitis, treat severe thread-worm infection, and relieve chest pains [10]. They are rubbed on the affected parts of the body or applied as a poultice [58].

3.3. Economic Importance

The estimated economic role of neglected crops such spider plant and obtain exact values in report form could be somewhat complex due to the nature of the crop, used by small scale and less attention of the stakeholders. However, the role of orphan crops in increasing economic and resilient agri-food system in sub-Saharan Africa estimated a large portion [29]. For instance, in Kenya, the production is now becoming a potentially profitable and considered as important families diet [69]. Sogbohossou *et al.* [73] reported that I tcontributed up to 40% of the rural small-scale farmer's income in Kenya. The similar result obtained by Weinberger and Pichop [80], who reported that annual turnover of 5.5 million USD. Market surveys conducted in Kakamega municipal market in western Kenya showed that African Leafy Vegetables constituted 20% in value for the traded produce during the period of the study [1].

Similarly, socioeconomic surveys conducted in various parts of African countries indicated that African Leafy Vegetables are important commodities in household food and nutrition security [5]. Women are known to be actively involved in the cultivation, processing, and marketing of African Leafy Vegetables. More than 95% and 70% of rural and municipal women participated in the marketing of spider plant in western Kenya [1]. Generally, the role of spider plant in economic sustainability is revealed directly and indirectly subsisting through supporting other growing agents in the societies.

3.4. Plant Protecting (Repellant Character)

Different studies showed the spider plant could be used in biological control due to its as insecticidal, antifeedant and repellent properties [63, 10]. Leaves of the crop expressed anti-tick and repellent properties for larvae, nymphs, and adult of Rhipicephalus appendiculatus and *Amblyomma variegatum*ticks [77]. It has the ability to repel at a distance of 2-5 m from the plant [60]. In addition, the ethanol extract from its tissue is toxic to insect pests, such as the painted bug (*Bagradacruciferarum*Kirk) and the diamond back moth (*Plutella xylostella* L.) of cruciferous vegetables [8]. Generally, extensive protagonist of spider plant in multi-dimensional ways was reported, however, improved variety of spider plant with desired characters is not yet reported due to different constrained in producers' countries.

4. Constraints of Spider Plant

Neglecting, stereotyping regarded as a weed and for the poorer in the societies put the crop far apart from improvements [10]. Another setback in spider plant improvement is the lack of awareness on it is nutritious and medicinal values hindering its improvements. Furthermore, exotic species, despite their inferior desired characters are promoted in favor of indigenous vegetables like spider plant in the view that they fetch a high income [34]. This has resulted in indigenous vegetables being neglected and mostly used for maintenance use.

Low seed quality, less agronomic improvement and lack of knowledge on existing genetic diversity is a major challenge in improving spider plant [34]. Production of spider plant in Africa is mainly done by smallholder farmers who use their own seed from season to season, with inadequate agronomic and seed quality control [1].

In the early of this decade, lack of adequate funding has led to limited research on indigenous vegetables especially setting up breeding programs in spider plant production and improvement [34]. Traditional and cultural methods of conserving genetic resources of the crop may no longer safe and need participatory conservation programs. The higher institutions and research centers focused on major crops which have been supported with enough budgets, while orphan crops observed under challenges in SSA. Furthermore, given less attention and undermined for poorest rural area people and counted as nonsense crop, focusing on exotic species revealed in African countries.

Although morphological, phenotypical, agronomic and genetic diversity of spider plant was studied, still not yet formal improved varieties [73], while farmers use traditional circulated in communities [34]. Therefore, improving activities in spider plant compared to its importance were less than constraints existed in an improvement. In addition, several genetic information of the crop, general and specific combining ability (GCA, SCA) and heterosis is not yet studied. However, there is an expectation that attention given to improving orphan crops provided to change in the way of existing in the societies and make to an order of exogenic vegetables crops in the future.

4.1. Genetic Variability's Status

Several studies of characterization carried out showed the existence of genetic diversity in the accessions of spider plant, while heterosis study is not yet carried out [33, 53, 65, 38].

Among the accessions of spider plants, emerging date, leaf formation, and days to flowering were significant variances existed [55]. This indicated the potential of existed genetic differences and variation among in farmers hand varieties. Phenotypic variations existed among spider plant accession were also reported among of traits such as petiole length, plant height, and days to flowering [50, 37, 10]. Similarly, molecular studies conducted on few selected similar plant morphotypes collected from western Kenya confirmed existences of genetic variation [59].

Munene [48] finding revealed that positives correlation between leaf yield and chlorophyll content, plant height, and a number of primary branches in spider plant genotypes. He was alosreperted stepwise regression showing that plant height had the most influence on yield in terms of a number of leaves per plant. Similarly, high heritability for several traits including days to flowering (91%), number of leaves per plant (99%), plant height (99%), number of primary branches (94%), chlorophyll content (94%), and single-leaf area (87%) were also observed. This is promising for improving yield in the crop through various plant breeding methods.

Omondi [51] indicated inter-country diversity to be greater than the intra-country diversity. Significant differences observed for most of the accessions grown in the field and glasshouse of Kenyan and South African accessions. A number of leaves per plant was significant and positively correlated with SPAD values of 34% and stem girth 59% for field and glasshouse grown accessions, respectively while, correlation value obtained from the field was greater than in glasshouse [52].

According to Kiebre *et al.* [38] variation were observed for plant height (27 - 100 cm), primary branches number (2 - 11), petiole length (2 – 16.44 cm), central leaflet width (0.7 – 7.22 cm), central leaflet length (1.2 – 12.10 cm), and biomass (16.4 – 474.7 g). In similar work, they reported that coefficient of variation for stem diameter (60.70%), petiole length (33.42%), central leaflet length (46.83%) and fresh leaves biomass (65.18%) in the accessions which was given high CV and large variations. Masuka et al. [43] reported that South Africa accessions recorded the variation of 25- 60cm in plant height.

Masuka *et al.*[43] and Kangai *et al.* [34] reported that heritability in broad sense of traits; number of primary branches, leaf length, leaf width, plant height, single leaf area, and SPAD ranged from 78% to 99% for spider plant accession collected from South Africa and Kenya. Specifically, high percentages of broad-sense heritability were estimated for plant height of 99% and 96% for SPAD heritability values recorded Kenyan and South African landraces [34]. Character traits were controlled genetically than phenotypic indicated in the studied showed that high broad-sense heritability (H^2) and weak differences between the phenotypic (PCV) and genotypic (GCV) coefficients of variation [44]. In contrast Omondi *et al.* [52] reported that they are greatly affected by environmental factors and the developmental stage of the plant; hence, classification schemes relying on these visible traits may not be as accurate.

4.2. Spider Plant Breeding

Extensive phenotypic and genotypic variation existed in spider plant which is important resources in its breeding [73]. It has been showed promised characters to improve in the future due to; widely adapted to the environmental condition including the areawere less favorable for other crops, early maturing, suitable reproductive organ and multipurpose in human life. For instance, Opondo *et al.* [59] reported phenotypic variations among growth characters of spider plant namely; branching number, stem and petiole length, plant height, days of flowering, central leaf length, and pigmentation. Furthermore, molecular studies conducted in Kenya was confirmed genetic variation which most important in the crop improvement [53].

Spider plant cultivation in different tropical countries also reported as variation existed with their genotypes. Evidently different populations could be found and collected in the different regions of Kenya, Tanzania, Benin, South Africa, Zimbabwe, Benin, Ghana, and others Asian countries which majorities of them different in agronomic traits, such as branching, stem color, leaf size, petiole length and color, and other morphological differences [73].

Though a huge variation of phenotypic differences reported, there is minute known extent and structure of genetic variation, the potential for crop improvement through the breeding of spider plant. Therefore, huge advantageous existed to improve spider plants using its opportunities. Successful breeding which footprint based on appropriate parental lines of provides high combining abilities in improvements with desired characters.

Various estimation of genetic variance and heritability in spider plant remained which breeders to guide them for increase breeding efficiency [38]. Such information provides an open door for the choice of the population to improve, and the adoption of the appropriate breeding procedure to obtain the best selection response [74]. However, information on genetic effects such as additive, or non-additive gene actions was not yet studied. Appropriate genetic evaluation, exploitation, estimation and generate information on its combining abilities with appropriate mating design should be required.

4.3. Pollination Methods of Spider Plant

Various methods of plant mating system have been used in crops improvements. In conventional breeding self and cross-pollination are the center of improvements and guided breeding methods. Therefore, the floral structure of crops guided the real procedures used to ensure self and cross-pollination. Wide pollination system in spider plant is possible under self and cross-pollination namely, open natural, cross, geitonogamy, and hand pollination techniques [73]. While the chances to be seed set was dissimilar.

4.3.1. Self-pollination

Self-pollination is essential procedures in crop breeding process [23]. The spider plant pursuing both of the self and cross-pollinates scheme of pollination [65]. Flowers opened in a sequence from the bottom of the inflorescence to the top. The staminate flowers and hermaphrodite flowers had the same shape and could open on the same day. Selfing is normally started within one to two days before anthesis if under field condition while possible to self in under controlled environments such as greenhouse after full anthesis.

Self-pollination has been accomplished in the field before the flower fully open means that after inflorescence initiated, while under controlled environments, required to manually pollination. Self-pollination is important to maintain the homogeneity of genotypes for the parental line. Seed set pods after fully matured should be collected by hand or manually to traces or released their seed and put appropriate places.

4.3.2. Cross-Pollination

Cross-pollination is the heart of crop improvement which may occur full natural, natural with interference and fully interference of breeders. Cross-pollination occurs between intraspecies which pollen of male parental line collect to dust on the stigma of female parental line. The objective of crossing is to generate hybrid vigor from desired characters of selected parental line. Due to hybrid vigorously, various increments existed in yield, qualities, and yield components of different crops. Cross-pollination of spider plant can be practiced at under controlled and field environments. The pollen is active at the nocturnal time between 15:30 to 18:00 which is critical for success in crosses [73].

To cross spider plant at the field, initiation of inflorescence before maturation of the pollen grain which yellow in color and specks of dust after fully matured, then removed out from the flowers to be crossed. The hermaphrodite flower of fertile gynoecium could be ready to accept pollen after full anthesis within 3 to 6 days. Similar to self-crossing, which use of pollen of the same plant to make pollination, in crosses, use the pollen of different plants of the same species but different accession based on parental line parameters of interest to be improved. The crossed plant should be tag by available tags, such as white tag or sometimes yellow is available. Fully matured pods of crossed plant collected and manually traced by trashing or squeezing our hands to protect the quality of seed from dispersing and seed breaking occur during trashing.

4.3.3. Heterosis and Inbreeding Depression

Heterosis, defined as the superiority of hybrids over their parents for quantitative traits, represents by crossbreed organisms as compared with inbred, as the results of dissimilar in the constitution of the uniting parental gametes [70, 22]. Heterosis exploitation is the most important in agriculture, which was added improved genotype in the production of crops and animals during the last of 20th century [18, 62]. It is an explanation relationship between genetic polymorphic and phenotypic variation in traits of organisms. Overall any advantageous character of improvements obtained from genetic recombinant is the positive side of heterosis.

Inbreeding depression refers to reduced fitness of progenies due to selfing of heterogeneous inbred line and mating of the relative parental line while, heterosis or hybrid vigor is the superiority of hybrid F1 over its parents [76]. Both heterosis and inbreeding depression are widely observed in both animal and plant kingdoms. There are three hypotheses of heterosis estimation [20, 16, 23].

(i). Mid Parent Heterosis

Mid Parent Heterosisis theperformed hybrid vigormean values difference from means of the two parents, it is sometimes called relative heterosis.

$$\text{Mid parent heterosis (Relative Heterosis\%)} = \frac{[F1-MP]X100}{MP} \quad (1)$$

MP=mid parent, $MP=\frac{[P1+P2]}{2}$, P1=parent1, P2=parent2, F1= progeny

(ii). Best Parent Heterosis (Hetrobeltosis)

Explained the superiority of hybrid vigor over the better parents which expressed in percentages.

$$\text{Heterobltosis (BPH\%)} = \frac{[F1-BP]X100}{BP}\text{, where: BP=best parent} \quad (2)$$

(iii). Economic (Standard) Heterosis

It refers to the superiority of the F1 hybrid performance over the commercial variety/ standard hybrid variety (Sv).

$$\text{Standard heterosis (SH\%)} = \frac{[Sv-F1]X100}{Sv}\text{, where: Sv= standard variety} \quad (3)$$

Heterosis is clearly related to heterozygosis, but it has been long debated how heterozygosis results in heterosis. It might be due to different factors of genetic effects; namely: dominance, overdominance and epistasis effects. While substantial debated on dominance or over-dominance effects, evidence of different studies indicated that both are not mutually exclusive [22].

The dominance hypothesis explains heterosis by the cumulative effect of favorable alleles exhibiting either partial or complete dominance, while overdominance hypothesis assumes over dominant gene action at many loci and the epistasis hypothesis attributes heterosis to epistatic interactions between non-allelic genes [66].

4.4. Overview of Combining Abilityof Spider Plant

Combining ability is defined as the cultivars or parent's ability to combine among each other during the hybridization process such that desirable genes or characters are transmitted to their progenies [21]. In another way, combining ability is an estimation of the value of genotypes based on their offspring performance in some definite mating design [3]. It is the capacity of an individual parental line to transmit desired characters and superior performance to its offspring. It is the phenomenon which inbred line crossed gives rise to hybrid vigor. Therefore, parental line and progeny tests should be performed to predict the combining ability of the characters governed by additives (recessive) and non-additives genes.

Combining ability is divided into two, namely; general combining ability (GCA) and specific combining ability (SCA). Both have had an important influence on inbred line evaluation and population development in crop breeding [75]. Sprague and Tatum [75] defined GCA as the average performance of a genotype in a series of hybrid combinations.

$$GCA_f = X_f - X \quad (4)$$

Where GCAf =general combining the ability of father, Xf= mean performance of father in its crosses, X= mean of all crosses.

$$GCA_m = X_m - X \quad (5)$$

Where GCAm =general combining ability of mother, Xm= mean performance of mother in its crosses, X= mean of all crosses.

Specific combining ability (SCA) is defined as those cases in which certain hybrid combinations perform better or poorer than would be expected based on the average performance (observation) of the parental inbred lines.

$$SCA_{(fxm)} = X_{fxm} - E(X_{fxm}) \quad (6)$$

Where: X_{fxm}=the observed mean value of the crosses indicating the true performance of the cross. E (X_{fxm}) = Expected mean value of the crosses.

$$E(X_{fxm}) = GCA_f + GCA_m + X, \text{ where, } X= \text{grand mean} \quad (7)$$

Parents showing a high average combining ability in crosses are considered to have good GCA while if their potential to combine well is bounded to a cross, they are considered to have good SCA. GCA is associated with genes that are additive in their effects, while SCA is associated with deviations from additive effects caused by dominance and epistasis [61].

Combining ability is analysis tool is useful for selecting favorable parents and provides information concerning the nature of gene effects influencing quantitative traits and, applicable to both self-pollinated and cross-pollinated species, for identifying desirable cross combinations of inbred lines to include in a hybrid program [21].

Combining Abilities estimation techniques

The procedures used to produces progenies and evaluate its parents combining abilities in breeding is refers to mating design [49]. Based on nature of the crop, objectives of the users (breeders and geneticists), and cost requirement to accomplish, different form and arrangements of mating designs were developed. Further, the choice of a mating design for estimate genetic variances dictated by the objectives of the study.

Thus, several studies [12, 24, 36, 26, 2] described types of mating designs so far: (1) bi-parental progenies (BIP), poly cross, top cross, North Carolina (I, III, III), Diallels (I, II, III, and IV) and Line X tester design. In all mating designs, the individuals are taken randomly and crossed to produce progenies which are related to each other as half-sibs or full-sibs, except polycross. A form of multivariate analysis or the analysis of variance can be adopted to estimate the components of variances. Furthermore, the mating design used in developed spider plant hybrids were NC II elaborated in the next topic. The NCII is factorial mating design which certain group of parents designated male (factor 1) and others female (factor 2) for use in crosses and useful for studying combining ability [21]. The design is often adapted to plants that have multiple flowers [50]. This design also allows the breeder to measure not only GCA but also SCA [2]. In NC II male and female effects are equivalent to GCA and male x female interaction represented SCA effects of the genes [25]. In NCII, GCA estimated separately for male and female, which make different and more advanced over diallel. Two independent estimates of GCA allow determination of maternal effects and calculation of heritability based on male variance, which is free from maternal effects. In addition, the NC II can handle more parents and produce fewer crosses than the diallel [17].

4.5. Combining Abilities and Heterosis Status

Combining abilities and hybrid vigor is different but mutually inclusive. This means a less parental line in combining abilities, provided less competent heterosis. The outcome of good combining ability is evaluated by virility of F1. The exploitation of heterosis or hybrid vigor has been adequately demonstrated in several cross-pollinated crops, such as maize, pearl millet and sorghum [19]. However, exploitation of hybrid vigor of F1 in a neglected crop such as spider plant is not yet reported even a substantial suitable to be developed a hybrid variety.

Extent, knowledge, and structuring of spider plant genetic variation studying are still on infant stage [9]. Therefore, these studies focused on an existed problem, tried to investigate GCA and SCA of some parental line and their progenies using NCII design collected from different parts of Africa. In addition, F1 generation obtained from those parental lines were studied at field and greenhouse to compare and recommend for further studied, use and sustainable production of spider plant.

5. Conclusion

Spider plant is incredible leafy vegetables uses for several purposes. But, it was less in promotion and need huge attention to improve its agronomic practices and genetic improvements. The huge opportunity existed in spider plant improvements are; mature early, adapt in wider of soil type, and less moisture contents. Further, less technology of improvements in agronomy and breeding ways showed as great opportunity to the agronomists and breeder including the improved technology such as biotechnology.

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