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Soybean Architecture Plants: From Solar Radiation Interception to Crop Protection

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Abstract

The soybean plant architecture in relation to better solar radiation interception and production gain is an aspect that requires a better understanding, since soybean is an important crop worldwide. The genetic traits, management and environmental conditions are points that further extend the range of issues on crop productivity. The light quality is measured by the red/far-red (R/FR) ratio ($R \sim 660$ nm, $FR \sim 730$ nm). This affects the plant growth and morphological developments in different ways. The plant leaves change their angle during the day to better intercept radiation. This heliotropic movement and some computational models together have been used to enhance some agricultural practices. Soybean plant is dependent on the interaction between genotype and environment. Thus, the enhanced understanding in relation to photosynthetic activity, grain yield by light interception efficiency and culture protection managements in soybean are covered.

Keywords: productivity, light, management, canopy, heliotropism

1. Introduction

The greatness of agriculture is natural transformation of solar radiation into fiber, oil, protein and carbohydrates. Management of plant arrangement, space organ distribution and plant density have to be appropriate for the maximum interception of photosynthetically active radiation in soybean plant canopy and for maximizing the dry matter accumulation during vegetative growth and early reproductive stages. The knowledge about the plant growth and development and their interactions with environment are essential for maintaining and increasing crop yield. More information is useful in plant management and breeding programs.

This chapter exposes the productive aspects of soybean plant and canopy architecture. Topics concern the characterization and definition of plant architecture, interception of solar radiation, CO₂ assimilation and yield, crop product deposition under the variations of plant/canopy architecture, crop managements and their impacts on architecture modifications. The definition of soybean plant canopy architecture aiming at aggregating knowledge and enhanced understanding of the increment in photosynthetic activity as well as the influence to grain yield of light interception efficiency and crop protection managements in soybean crop are assessed.

2. Characterization and definition of soybean plant architecture

Architecturally, soybean plants can be regarded as a continuum born from the successive production of metameric units. One metameric unit consists of an internode, a trifoliolate leaf and the associated reproductive branch born at respective node. The structure of the whole plant can suffer modifications. These are due to the genetically or environmentally induced modification of the structure of each individual metamere or of its number [1].

Plant architecture refers to the organization of plant components in space which can change with time. Furthermore, architecture can be defined by topological and geometric information. Topology is related to the physical connections between plant components. Geometric information includes the shape, size, orientation and spatial location of the components. Thus, the geometry is mostly involved in plant environment exchanges and resource capture. However, the topology can be used to build up biological sequences embedded in axes or still can be considered as the basis for internal fluxes for energy, mass and information [2].

In relation to size and shape of leaflet, Zheng and Chen [3] proposed three classes for leaflet size (small, intermediate and large) and four categories for leaflet shape that has been lately corrected by Chen and Nelson [4] considering five categories for leaflet shape—oval, ovate, lanceolate, linear and ultra linear. Length/width ratio and length are chosen to define leaflet shape and leaflet size, respectively. Values of length/width ratio ranged from 1.3 to 6.2 and those of length from 3 to 14 cm [4].

The soybean plant morphology and architecture are determined by branching and internode length [5], whereas its growth and development are affected significantly by a cultivar-specific temperature regime [6]. Thus, flowering time, number of pods, maturity and plant morphology are complex traits controlled by genetic and external factors. These characteristics have considerable effects on the adaptation and grain yield of soybean. The identification of novel genes and an understanding of their molecular basis and mechanisms involved are critical to improve soybean productivity. Characteristics associated with soybean yield components and plant architecture are substantially correlated with both genotype and phenotype [7].

The involvement of the single nucleotide polymorphisms (SNPs) in the plant architecture and yield component traits has been established [7]. These traits are severely influenced by environmental factors. The *ln* locus (*ln* locus named after narrow leaflet) was identified as a regulator of leaflet shape and number of seeds per pod in soybean. This suggested positive

applications to soybean breeding [8]. The IPA1 locus (ideal plant architecture 1) [9] has an ability to generate an ideal plant architecture with reduced tiller number. Recent studies suggest that the genetic modulation of brassinosteroid (BR) receptor genes can alter plant architecture [10]. In soybean, investigations are still needed to confirm the relationship between BR receptor genes and plant architecture. However, the transcript abundance of BR receptor genes in nodules, apical buds, cotyledons, epicotyls, hypocotyls, leaves, lateral roots and primary roots was demonstrated, implying that the genes play an important role in soybean growth and development [10].

Class I KNOX homeobox family genes are involved in the plant growth and development, especially in the growth and development of leaves, flowers and pods [11]. *GmSBH1* is a homeobox gene isolated from soybean, which showed diverse expression patterns in cotyledon, embryo, seed coat, seedling stem, seedling root, flower and pod. The overexpression of *GmSBH1* in *Arabidopsis* altered the leaf and stoma phenotypes. This result demonstrates that *GmSBH1* is required for maintaining growth and development in soybean [11]. Overexpression of a flowering time-related *APETALA2-like* gene *GmTOE4a* caused late flowering and altered soybean plant morphology (increased stem thickness and reduced plant height, internode length and leaf size) [12], demonstrating that the gene plays a role in the regulation of the photoperiodic flowering pathway in soybean. The miR156 and miR172, microRNA genes, are known to be associated with vegetative phase change. In soybean, it was shown that miR156 and miR172 genes are involved in the change from juvenile to adult phase, thus demonstrating that the genes play an important role in plant development [13]. In soybean plants overexpressing miR156b, flowering time was suppressed and other genes were negatively regulated [14]. These results, in near future, may facilitate the development of new soybean cultivars with high yield potential as well as more adapted cultivars to environmental conditions.

The soybean varieties with determinate growth permit the lower number of metamere units per main stem and lower competition between the vegetative and reproductive growth and maturation, leading to higher grain production [15]. The indeterminate type varieties have much more internodes at the main stems, which are consequently longer than those of determinate cultivars. Indeterminate type varieties continue to elongate their stems for about 1 month after the beginning of flowering, while determinate ones stop their elongation after 10 days from flowering [16].

The search for an ideotype that has a good genetic potential to overcome the environmental adversities and presents high productivity is a challenge for agriculture worldwide. One genotype may have a good performance in a given region, which may not be ideal for another. Likewise, in different years of cultivation in the same place, the response may vary. Therefore, genotype and environment corroborate specific responses. **Table 1** shows the variation between soybean genotypes for some agronomic traits that define plant architecture.

The light quality is measured by the red/far-red (R/FR) ratio (R ~ 660 nm, FR ~ 730 nm). Light that has passed through a leaf canopy is rich in FR light but poor in R light [23]. The R/FR ratio decreases from ~1.2 in full sunlight to 0.05 in closed canopies, with a decrease occurring before canopy closure by absorption of red light by photosynthetic pigments [24]. Plants that detect a low R/FR ratio will initiate some physiological changes and like this, plants express

shade avoidance characteristics [25, 26]. In an experimental system of modification in the R/FR ratio under relay intercropping with maize and soybean, decreases in stem diameters (20.3 and 21.3%) and root length (23.5 and 30.5%) and an increase in the seedling height (approximately 89.8 and 86.9%) were observed for two cultivars, as compared to those under sole cropping [27].

Characters	References
Plant height (cm)	
34.3–62.4	[17]
51.15–58.35	[18]
44.87–82.75	[19]
76.0–102.3	[20]
First pod insertion height (cm)	
4.41–12.77	[17]
11.15–11.95	[18]
7.85–12.50	[19]
Internode length (cm)	
2.47–2.83	[18]
Number of branches*	
1.87–1.88	[18]
3.25–6.77	[19]
3.0–7.4	[20]
Length of primary branches (cm)	
22.92–24.53	[18]
Number of nodes on the main stem	
19.0–24.7	[21]
Leaf area index (leaf area per unit ground surface area)	
3.3–6.6	[20]
5.6–9.8	[22]

*Average number of branches in different soybean cultivars; Ref. [18]—considered the branches over 5 cm; Refs. [19, 20]—considered the total branches of plant.

Table 1. Range of the values (minimum and maximum) of agronomic traits of different genotypes of soybean.

The competition between plants in the canopy is detected by an alteration in R/FR light ratio. This alteration affects the apical dominance and the growth of lateral organs. It occurs because light signals are perceived by the phytochrome, which has a function in detecting the level of competition plants will encounter [28]. In general, there is an increase in the plant stature in response to the decrease in light quality. It is important to emphasize that phytochromes

(PHY) are a small family of R/FR light photoreceptors which regulate several of important developmental responses in plants, such as rapid biochemical events and slower morphological changes. A pair of PHYA paralogs (*GmPHYA1* and *GmPHYA2* genes) of the soybean has been explored. The expression pattern of the genes varied among tissues. The high transcript abundance was in the soybean seedling and hypocotyl, suggesting that the PHYA products could be involved in aspects of seedling establishment and photomorphogenesis. In addition, the transcripts showed abundance in the younger leaves [29].

The plant growth to light direction is called phototropism, which is a photomorphogenic response. Plants are cultivated under a source of a directional light curve themselves to the light direction to maximize the light absorption and this response is mediated by the blue light [30]. There are proteins involved in the phototropism, which are named phototropins (phot1 and phot2). Besides the phototropism, these proteins are involved in chloroplast movement, quick growth inhibition of etiolated plants, leaf expansion and regulation of stomatal aperture [30].

The reduction in the ozone layer has an effect to increase ultraviolet radiation reaching the earth's surface, especially the radiation of ultraviolet-B (UV-B). High levels of ultraviolet radiation influence negatively on carbon assimilation rate and growth of plants [31]. The alterations in plant height, branching pattern and leaf size of soybean plants were observed in UV-excluded sunlight when compared to control plants. The exclusion of UV radiation increased leaf dry weight (43%), leaf fresh weight (22%) and leaf area (54%). In addition, the exclusion of solar UV-B and UV-B/A radiation increased the plant height (30% for exclusion of UV-B and 60% for exclusion of UV-B/A). Thus, the solar spectrum causes changes in soybean growth and morphological developments [31]. The exclusion of the UV-B/A radiation also caused elongated internodes in soybean plants, resulting in greater plant height. Increases in the main stem length were also observed for exclusion of both UV-B and UV-B/A (45 and 237% in one cultivar and 52 and 198% in other cultivar). The number of the branches was not affected by the UV treatments and the total leaf area was less in plants exposed to UV radiation [32].

The leaves of some plants including soybean have an important characteristic of altering their angle during the day aiming to adjust the intercepted radiation. This movement is called heliotropism, which is induced by the blue light (400–500 nm) [33]. The heliotropism is divided into two leaf movements which are called diaheliotropism and paraheliotropism [34]. Diaheliotropism is a movement maintaining the leaf blades perpendicular to the solar rays, maximizing light interception with carbon gain [35]. Paraheliotropism is a movement maintaining the leaf blades parallel to the solar rays and reducing the effects of hydric stress [36], photoinhibition [37] and high leaf temperature [38]. Genotypes respond differently to heliotropism and besides that, those responses differ during the cultivation cycle and under stressing conditions [39].

The heliotropic movement can be used to enhance some agricultural practices and hence, some computational models have been adopted. Computer modeling has become an important tool to enhance understanding of development and growth of the plants. In the modeling development, the functional-structural plant modeling refers to models describing the

development over time of the 3D architecture or structure of plants as guided by physiological processes which, in turn, are driven by environmental factors [40]. Thus, simulation models can be used to predict the outcome of plant trait modifications resulting from the genetic variation and also its interaction with the environment on plant performance, contributing to plant breeding process [41].

3. Solar radiation interception, carbon fixation and grain yield

Soybean presents high levels of carbon fixation with the maximum air temperature of around 30°C and photosynthetically active radiation leading to saturation is proximally 2000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ [42]. These may be reasons why the origin of soybean is East Asia. However, some models demonstrate a high photosynthetic activity at a temperature of 35°C with a photon flux density of 1200 $\mu\text{mol m}^{-2} \text{s}^{-1}$ and internal CO_2 concentrations above 800 $\mu\text{mol CO}_2 \text{ mol}^{-1}$ [43]. Historically, with genetic improvement in soybean crop, there have been considerable modifications in plant architecture components with the goal of improving mechanization efficiency principally on the height of insertion of pods. At the same time, harvesting technology has also advanced. However, a number of cultivars continue with the insertion of the first legumes higher than what is necessary to actual reality of the field.

Photosynthetically active radiation interception (PAR_{int} , $\mu\text{mol m}^{-2} \text{s}^{-1}$) is highly variable depending on plant population in the fields, the environmental conditions and plant genotypic characteristics including plant structure. In **Figure 1**, we can observe the PAR_{int} and the relation with grain yield in two equal parts of four soybean genotypes cultivated in Brazil. We can also observe significant differences in plant architecture between the four cultivars. There is also a reflex on solar radiation interception in the under part of vegetative canopy, which is divided into two equal parts. Generally, plants that receive more solar radiation in the upper part have higher grain yield in the upper and medium part (**Figure 1**) (Müller 2016, unpublished data). Nevertheless, it must be highlighted that this is not always true; there is a dependency on a number of definition factors of yield, especially about drainage capacity of photoassimilates for the grains that deal with a variable characteristic between genotypes, signalized in a larger scale by cytokinin hormone [44].

The lower availability of solar radiation can be reflected in the grain yield due to net fixation of carbon. The quality of light is also important, especially considering the relation between red wavelength and extreme red that can speed up the process of senescence of the soybean leaves. Burkey and Wells [45] observed the influence of light on the acceleration of senescence process of soybean leaves. As a result, it is clear that the light of solar radiation is important in the production of photoassimilates and the maintenance of photosynthetic activity.

In sun plants, as soybean, the light compensation point (the amount of photosynthetically active radiation where net fixation is zero) is located in 10–20 $\mu\text{mol m}^{-2} \text{s}^{-1}$ [30]. Thus, solar radiation above this value is necessary in order to have increment in carbon fixation and reflection on growth and yield. There is a strict relationship between the availability of nitrogen and photosynthetic activity [46]. Variations of nitrogen in the plant were obviously

related to its availability in soil [47] and the variations can be attributed to the vegetative canopy, especially involving the age of the leaf and the availability of solar radiation [48]. Models demonstrate relations between lower light interception and the fall of the protein content in the vegetative canopy as well as variations of the protein content with the availability of direct and diffuse radiation [49].

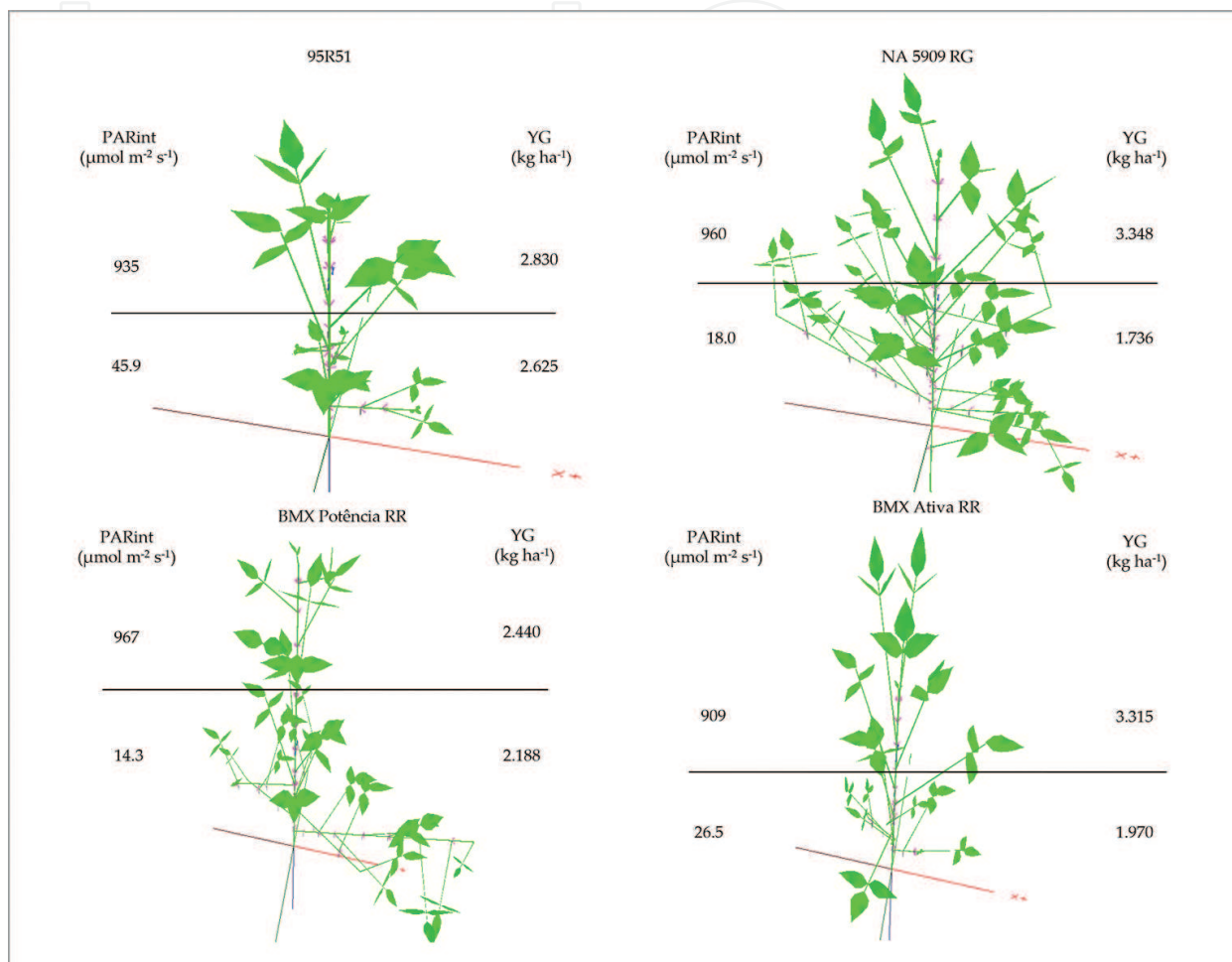


Figure 1. Architectures of vegetative canopies of four cultivars of soybean and photosynthetically active radiation interception (PARint, $\mu\text{mol m}^{-2} \text{s}^{-1}$) and grain yield (YG, kg ha^{-1}) (Müller 2016, unpublished data).

The capacity of nitrogen use by the plants is intimately connected to the availability of light in relation to the activity of the photochemical stage of photosynthesis [49]. In this stage, reducing agents are generated that will reduce nitrate to nitrite and afterwards, to ammonia that will be assimilated in the form of amino acid. This process known as “photoassimilation” is crucial for the metabolism of the plants and therefore, it is easily comprehended that as long as the quantity of light is reduced through the vegetative canopy, the process of photoassimilation will also be reduced [48]. One of the possibilities for increasing photosynthetic production through genetic breeding, challenge is the obtainment of the soybean cultivars that have a major activity and amount of RuBisCO as well as of other enzymes involved in

the photosynthesis, which would result in a larger demand for nitrogen [50]. Thus, the light interception would have to become more efficient to support cultivars with larger demands of nitrogen and subsequently more photoassimilation.

In soybean, symbiotic nitrogen fixation and how the energy used in this process originates in the photosynthesis are very important. The variation in the solar radiation interception due to the architecture can influence these processes. For the production of 1000 kg of grain are necessary around 85 kg N ha⁻¹, of which around 60–90% are available by the symbiotic nitrogen fixation through diazotrophic bacteria. However, around 14% of the photoassimilates produced by soybean plants are used for this process [51]. This fact strongly suggests that the architecture of the plants that can define the capacity of solar radiation interception has a strict relationship with the capacity of symbiotic bacteria in the soybean plants fixing atmospheric nitrogen.

The light extinction coefficient (k) is an attribute that is related to the solar radiation interception and the architecture of the plants mainly in the vertical distribution of the leaves [52]. The k provides information about the transmissibility of solar radiation through the vegetative canopy not only by the relation of leaf area but also by the variations that may result from distinct plant architectures. The extinction coefficient (k) is defined as $\ln(1 - \varepsilon_{\text{int}}) = -k \cdot \text{LAI}$, ε_{int} = efficiency of the solar radiation interception, determined from quotient between the solar radiation intercepted and total incident on the canopy and LAI = leaf area index, total leaf area per unit ground surface area [53].

In soybean crop, the high capacity of the solar radiation interception was observed with values of 0.52 and 0.93 before and after flowering, demonstrating high potential of interception of solar radiation per unit of LAI [54]. Ebadi et al. [55] studying 17 soybean genotypes observed minimum and maximum values of 0.44 and 0.62, respectively. It is highlighted that phenomenological stages exist in soybean crop in which the exposure to solar radiation presents more influence on the determination of grain yield. Later stages of the vegetative period and of the beginning of the flowering are determinant for definition of the number of legumes [56]. The restriction of 25% of solar radiation when compared with the environmental conditions in the beginning of the flowering can modify the availability of photoassimilates at the point of influencing effective fructification and compromise the grain yield [57].

Studies of genetic dissection and relations of the plant architecture with yield composition demonstrate positive correlations among the number of branches in the main stem, total number of nodes, diameter of the stem in the third node with a number of legumes, number of grains per legume and total grains per plant [7]. Soybean presents a high relation between production of biomass in shoot part and interception of solar radiation even in the phenological stage of physiologic maturation [58]. The efficiency of the use of radiation is the result of the gain of dry mass in relation to PAR_{int} accumulated [59]. The literature presents varied values of efficiency of the use of radiation in the range from 1.23 to 2.53 g MJ⁻¹ PAR [60, 61]. In general, it is known that higher values of efficiency of the use of radiation are observed in the reproductive period of the soybean crop.

Considering that the composition of the soybean grain yield is defined by the fertility of the nodes, that is, effective fructification, the number of legumes and number and mass of the

grains, the production of sugars originating in the photosynthesis is fundamental to compensate this energetic cost. Among the great challenges of the increase in grain yield in soybean crop, fructification is highlighted. A number of factors are involved in this process, from the hormonal action by the definition of drainage organs and the formation of structures [44], the mineral action by movement of sugars (K, Mg and B), structuring (Ca, B and Mg) [62] and the availability of sugars for production of carbon skeletal and ATP [63]. To last factor, the availability of solar radiation is a primary function for photosynthetic activity to produce photoassimilates.

The availability of solar radiation is reflected in the environment temperature. In some soybean production regions that are exposed to higher temperatures, it is common to observe that in some years there is less solar radiation available, which results in major gains in yield. This is likely to be related to the decrease in metabolic losses in the processes of respiration and photorespiration that results from lower temperature.

The breeding programs should be more emphatic in studies related to the architecture of soybean plants. In general, a number of important actions are taken to deal with biotic (pests and diseases) and abiotic (drought resistance) stresses. However, the selection of materials aiming at the photosynthetic efficiency by means of architectural variations is little explored. Koester et al. [64] evaluating 24 soybean cultivars liberated from 1923 to 2007 in the United States observed that maximum photosynthesis, stomatal conductance and nocturnal respiration were not significantly modified throughout these years. Nevertheless, the authors also observed that the daily biomass gain was higher in newer cultivars and suggested that this better performance was associated with a higher content of chlorophyll and the drainage capacity in reproductive organs. Ustun et al. [65] verified that the masses of the cultivars between 1940 and 1970 were considerably small, demonstrating that there was increase in drainage capacity of reserve for the reproductive organs in the cultivars.

4. Spray deposition under variations of plant architecture

With the aim of increasing and improving agricultural production, the number of applications of phytosanitary products during the cultivation cycle has been elevated, burdening with production costs and risks of contaminating the operator and the environment. In this sense, the application technology has been improving, permitting an improvement in the deposition of active ingredients in the desired target.

The application success depends on many factors. Some are controlled by the farmer and some not. Among the possible control factors are type of product, type of equipment, volume of solution, droplet size, application frequency and moment of application. However, some factors have a direct influence on pulverization quality of the phytosanitary products and cannot be controlled by the farmer, such as the architecture, the phenological stage and anatomical and morphological characteristics of the plants.

The variability among different soybean cultivars in relation to the architecture influences the deposition of droplets in the plant strata. The low penetration of active ingredients in the

plant canopy interior is mainly due to the so-called umbrella effect of the superior leaves. This contributes to the spread of diseases, because beyond not having protection, the lower part (one-third) has a microclimate that favors the occurrence of diseases, especially fungal diseases.

The efficacy of the application technology to disease control can be determined by the number and size of the droplets that reach the target per cm^2 . The quantities of droplets depend on the characteristics of the product to be applied. For an effective control, a coverage of around 30–40 droplets and coverage of around 50–70 droplets per cm^2 are needed for systemic fungicides and protective fungicides, respectively [66]. Even considering the variation in the types of tips and flows, the volume deposited in the lower part (one-third) is significantly inferior to the amount deposited in the higher part (one-third) [67]. This amount can be up to three times higher than the lower part (one-third) [68]. Wolf and Daggupati [69] observed only 10% coverage of the tissue in the lower part.

Leaf diseases reduce the healthy photosynthetic leaf area, decreasing the solar radiation intercepted and the capacity of radiation use, which consequently may cause the leaf fall. It is easily inferred that the grain mass is negatively affected by the premature leaf fall and therefore, losses occur in the yield and in the quality of the final product. The visual appearance of the leaf diseases does not always represent the impact in the photosynthesis. When plants infected with the fungus *Phakopsora pachyrhizi* were evaluated, the disease impact in photosynthetic activity was larger than the visual estimation [70].

The application of phytosanitary products in alternate hours of the day can be an alternative to make this practice more efficient with more active ingredient in the inferior part of the canopy. It is observed that superior leaves are less affected by the “umbrella” effect in certain times of the day, due to angulation change of the leaves by the heliotropic process. The angulation of the leaves in diaheliotropism in the early morning and late afternoon can hamper the droplet penetration in the plant inferior stratum. However, the angulation of the leaves in paraheliotropism in the late morning and early afternoon can decrease the physical barrier of the plant higher stratum in the penetration of phytosanitary products.

Climatic factors such as temperature, relative humidity and wind speed must be monitored to avoid evaporation and droplet drift [71]. These environmental conditions cannot be favorable to pulverizing in the moment when the plant superior leaves are in greater angulation compared with the soil. Thus, we believe that when possible to conciliate the leaves angulation with environmental condition in the pulverization moment can increase disease control efficiency. Architecture characters that mostly influence droplet deposition in the plant are stature, the number of branches and size and number, format and orientation of the leaves. Plants with larger stature, a higher number of branches and higher LAI present the higher variations in droplet deposition [20].

Biotic and abiotic factors are variable conditions between systems and years of cultivation, to which the farmer needs to optimize the crop management adequately. Hence, the following question is proposed: which is the architecture that is proportionate to a better efficacy in phytosanitary product deposition, resulting in an effective participation of all parts (all three equal parts) of the plant in the grain yield among different cultivation conditions?

5. Crop managements and their impacts on architecture modification

Excessive growth in soybean plants has caused lodging, damaging the harvest, besides hampering phytosanitary managements and light interception in the canopy interior. This excessive growth is due to fertilization, climatic conditions, sowing density and season and the own characteristics of cultivars used. Plants with higher stature do not mean higher yield and many times occurs the contrary, since the plant uses much energy to produce green mass instead of sending this energy for grain production and filling, besides causing self-shading.

With the aim of making soybean plant architecture more efficient in the use of environmental resources, growth regulators have been used. These substances are applied exogenously and influence the physiological processes, stimulating and/or inhibiting cell elongation or division.

Apical bud growth can inhibit axillary bud growth due to the apical dominance caused by the auxin hormone. Inhibitors of auxin transport, such as the 2,3,5-triiodobenzoic acid (TIBA), can eliminate the inhibition of axillary buds [30]. TIBA when applied in stage V5 of soybean in which fourth trifoliolate leaves are completely developed [72] reduced the plants stature without negatively influencing yield-related parameters [73].

Some vegetal regulators can inhibit the synthesis route of gibberellic acids synthesized by vegetables. Plants treated with these substances can present characteristics of agronomic interest different from those not treated, which can benefit some cultivation traits. Trinexapac-ethyl doses did not interfere in the components of soybean yield, but altered the plant stature and stem diameter [74]. Nonetheless, other authors who applied the same regulator found a reduction of 12% in the yield [75].

The use of chlormequat chloride and chlorocholine chloride in soybeans presented significant differences in reduction in stature and in effects on flower dry mass, root dry mass and root/aerial part ratio and in the number of flowers, besides reducing the leaf area, the dry mass of legumes and the total dry mass of plants [75]. The use of growth regulators when applied in the right moment and in the right doses has provided positive results in soybeans. Growth regulators can modify the architecture in a way that light interception and phytosanitary management are beneficial, making it possible for the farmer to make strong fertilizations and use genotypes with a high genetic potential for grain yield, even though they present exaggerated growth.

The adjustment in plant arrangement through sowing density and width can be proportionate to positive results due to a better soil coverage, a greater weed control, a decrease in intraspecific competition, an increase in the use of water and nutrients, the interception of solar radiation and better phytosanitary management. Adjusting sowing density is important to optimize the cultivation growth and the time necessary for the canopy closure. Shading caused by plants' high density especially in the plant lower part (one-third) harms the cultivation productive potential. This is due to the lack of collaboration of these shading structures in carbon assimilation and consequent decrease in the maintenance and grain filling.

Soybean plant width and density vary according to the characteristics of cultivars and environments. Hence, the potential of cultivars can be optimized by the adjustment of width

through the plant density, growth habit and climatic conditions. Soybean has the capacity to adjust itself to different environments and managements due to its plasticity [76].

Sowing density recommended above by the breeder might cause the development of higher plants with a reduced stem diameter, generating the plants more vulnerable to lodging. The number of branches and legumes, grain yield and thousand grain mass per plant decreases with the increase in plant density [77]. An increase in density maximizes the competition between plants of the canopy, being a possible factor for the reduction in branches per plant. A reduction in the number of branches per plant from 0.26 to 0.05 in two cultivars for each additional plant per m^2 was observed [78]. Meanwhile, low plant density might have increased the number of branches with a major contribution of them with the total yield. A small plant population results in larger grain yield through the increase in the number of fertile legumes per m^2 and higher grain weight due to a decrease in intraspecific competition [79].

The period of sowing must be planned having in mind the effort to avoid unfavorable environmental conditions principally in the critical period, which starts at the flowering and goes up to the grain filling. Any kind of stress in this period can affect negatively the crop yield components. However, cultivars response to photoperiod and temperature are distinct, being some more sensitive than others. Thus, the most appropriate time of sowing for each cultivation and environment must be evaluated.

Early sowing can increase LAI and increase grain yield. However, it can also promote self-shading and lodging by excessive vegetative growth [80]. When the photoperiod is prolonged in the moment of grain filling, it permits a higher duration of this phase, enabling an increase in the seeds through a higher number of nodes and more legumes per node [81]. In late sowing occur the early flowering, reduction in cycle and stature of the plant as well as a negative association between emergence date, maturation and stature of the plant [82]. The crop will present lower vegetative growth due to high temperatures and shortening of days in the beginning of the cycle, inducing the flowering even in small plants and lower LAI. Thus, grain yield can be harmed by alterations in the plant morphology and architecture [76]. In the southeast of Brazil sowing on November 11 and 26, reduction in the plant stature at flowering and maturation and in the number of days for maturation was observed when comparing the second season with the first. Also, the delay of 15 days in the sowing resulted in an increase in the height of insertion of the first legume, while the weight of 100 grains and the yield were not influenced by the sowing period [83].

Soybean is a plant highly dependent on the interaction between genotype and environment. Soybean can change its cycle and vegetative growth, depending on this interaction. Soybean cycle duration depends on the floral induction's photoperiod and temperature. These factors are reflected in plant architecture, cycle and crop yield potential.

6. Final considerations

The soybean has a high genetic potential for grain yield. However, there are several interferences during the cycle that can compromise the potential. We believe that the soybean plant architecture directly affects the final yield of the culture through the low efficiency in

interception of solar radiation and the difficulty of controlling disease, especially in the lower strata of plants.

Improving plant architecture can bring the benefit for further exploring natural ingredients that are the sun's raw materials. Improvement in phytosanitary management can reduce the number of the applications during the cycle, with consequent reduction in production costs and environmental risks. Thus, it is suggested that studies are carried out to evaluate the architecture in relation to interception of solar radiation and deposition of active ingredients. This will contribute to breeding programs to develop the plants that adjust the morphology in relation to these aspects, contributing to a genetic gain and social.

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