



ELAINE CRISTINA BATISTA

**IS IT FEASIBLE TO SELECT FOR FLOWERING SET IN
SOYBEAN?**

**LAVRAS - MG
2023**

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Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Agronomia/Fitotecnia, área de concentração em Produção Vegetal, para a obtenção do título de Doutor.

Prof. Dr. Adriano Teodoro Bruzi
Orientador

Dr. Carlos Eduardo Pulcinelli
Coorientador

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Ficha catalográfica elaborada pelo Sistema de Geração de Ficha Catalográfica da Biblioteca
Universitária da UFLA, com dados informados pelo(a) próprio(a) autor(a).

Batista, Elaine Cristina.

Is it feasible to select for flowering set in soybean? / Elaine
Cristina Batista. - 2023.

79 p. : il.

Orientador(a): Adriano Teodoro Bruzi.

Coorientador(a): Carlos Eduardo Pulcinelli.

Tese (doutorado) - Universidade Federal de Lavras, 2023.

Bibliografia.

1. *Glycine max (L) Merrill*. 2. Estratégias de melhoramento em
soja. 3. Interação Genótipo x Ambiente. I. Bruzi, Adriano Teodoro.
II. Pulcinelli, Carlos Eduardo. III. Título.

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É POSSÍVEL SELECIONAR PARA VINGAMENTO FLORAL EM SOJA?

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APROVADA em 28 de fevereiro de 2023.

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Aos meus pais Edvani e José Mauro, pelas palavras de incentivo e encorajamento e pelo constante apoio em todas as minhas decisões, para que eu pudesse me tornar o que hoje sou. À minha irmã Bia, pelo companheirismo e amor. Ao meu marido Mike que esteve ao meu lado durante essa caminhada, me incentivando e acreditando nos meus sonhos.

Dedico

AGRADECIMENTOS

A Deus, que incessantemente olha por mim.

Aos meus pais, exemplo de fé, luta, humildade e amor.

Ao meu marido por todo o amor. Por ser o meu descanso e minha calma.

À Universidade Federal de Lavras, pela oportunidade de realização do doutorado e pelos conhecimentos adquiridos.

Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), pelo suporte financeiro. O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) – Código de Financiamento 001.

Ao amigo e orientador, Dr. Adriano Teodoro Bruzi, pelo exemplo de profissionalismo, pelas orientações valiosas e por me proporcionar esse aprendizado. Por me orientar não somente neste trabalho, mas na vida. Sempre disposto a ter discussões enriquecedoras, buscando proporcionar-me as melhores oportunidades.

Ao professor Samuel Fernandes, da Universidade do Arkansas/ EUA, pelo auxílio nas análises estatísticas realizadas nesse trabalho e pela prontidão em ajudar.

A todos os professores do Programa de Pós-Graduação em Fitotecnia, pelo conhecimento compartilhado.

À secretária Marli, pela gentileza com que sempre me atendeu.

Ao grupo *Pesquisa Soja* onde fiz grandes amigos. Desejo que vocês tenham muito sucesso.

Obrigada pelos momentos de companheirismo, pelo convívio, pela troca de conhecimentos e por todas as flores que contamos juntos durante os últimos anos. Não foram poucas.

À Universidade do Arkansas/ EUA, pelo período de aprendizado como pesquisadora visitante.

Ao Dr. Leandro Mozzoni pela oportunidade que me foi dada de fazer parte de seu grupo de pesquisa. Obrigada por confiar no meu trabalho, pelas conversas e conselhos.

Ao Dr. Jeff Edwards (Universidade do Arkansas/EUA) pela supervisão e orientação.

À Daniela Kidd (Universidade do Arkansas/EUA) pela amizade e pelo cuidado que sempre teve comigo. Que alegria a ter encontrado!

Aos amigos do *Soybean Breeding Group* da Universidade do Arkansas/EUAs: Liliana Florez, Derrick Harrison, Andrea Acuna, Ali Ablao, Daniel Rogers, Chengjun Wu, Joshua Winter. Sou grata pelos momentos que passamos juntos e por todo o aprendizado e crescimento profissional que me foi proporcionado.

À minha amiga Francia Ravelombola da Universidade do Missouri/EUA, pela amizade e pelo auxílio em tantas atividades do trabalho. Com você aprendi que a vida deve ser sempre

celebrada e que todos os dias, todas as situações, têm algo de bom para ensinar, basta saber enxergar.

À minha amiga Trang Do, pela amizade e pelo carinho que sempre teve comigo. Você fez minha estadia em Fayetteville-AR ser ainda melhor.

À minha família, em especial ao meu padrinho Geraldo (*in memoriam*) que tanto se alegrou com minha aprovação no doutorado e sempre torceu por mim.

A todos que de forma direta ou indireta participaram dessa etapa de minha vida, e que não foram citados aqui, mas Deus sabe e trará a recompensa.

Muito obrigada!

*“A vida inventa!
A gente principia as coisas,
no não saber por que,
e desde aí perde o poder de continuação
porque a vida é mutirão de todos,
por todos remexida e temperada.
O mais importante e bonito, do mundo, é isto:
que as pessoas não estão sempre iguais,
ainda não foram terminadas,
mas que elas vão sempre mudando.”*

(Guimarães Rosa, fragmento do livro Grande Sertão Veredas)

“Até aqui me ajudou o Senhor”.

I Samuel 7: 12

RESUMO

Em soja, a produtividade potencial de grãos é dependente do número de plantas por área, número de vagens por planta, número de grãos por vagem e o peso médio dos grãos. A contribuição de cada um desses componentes primários de produção é variável, contudo, em algumas situações o número de vagens por planta tem se mostrado importante. O número de vagens é dependente do número de flores produzidas pela planta e o seu vingamento, ou seja, a proporção de flores que originam vagens. Em soja, normalmente o número de flores por planta é muito superior ao de vagens, logo, o vingamento floral quase sempre é pequeno. Por consonância, a planta não tem condições de expressar todo o seu potencial produtivo, visto que alguns estresses (bióticos ou abióticos) afetam o vingamento das flores. Objetivou-se determinar o vingamento floral de progênies de soja com diferentes grupos de maturidade; A resposta correlacionada entre vingamento floral e produtividade de grãos de soja; Viabilidade de seleção para o caráter de vingamento floral. Os experimentos de campo foram conduzidos durante as safras 2019/2020 e 2020/2021, nos municípios de Ijaci, no Centro de Desenvolvimento e Transferência de Tecnologia em Agricultura da UFLA – Fazenda Palmital, e no município de Lavras, no Centro de Pesquisa Científica e Tecnológica em Agropecuária-Fazenda Muquém. As progênies F_{2:4} e F_{2:5} foram avaliadas em dois experimentos: um contendo progênies precoces e testemunhas e outro com progênies tardias e testemunhas, ambos conduzidos sob o delineamento de blocos completos casualizados (DBCC). A parcela foi constituída por duas linhas com três metros de comprimento e espaçamento de 0,5 metros. Na parte central, foram selecionadas seis plantas na primeira linha de cada parcela, onde foi colocado um receptáculo floral, com o objetivo de coletar estruturas reprodutivas que seriam abortadas. Foram avaliados os caracteres agrônômicos dias para plena maturidade (DTM), produtividade de grãos (YIELD), hábito de crescimento (GROWTH) e vingamento floral (FS). As análises estatísticas foram realizadas no ambiente R, utilizando modelos lineares mistos (LMM) e modelos lineares generalizados (GLMM). A etapa inicial de análise dos dados envolveu o ajuste de modelos lineares mistos e modelos lineares generalizados aos dados fenotípicos de cada caráter. Apenas os efeitos fixos que foram significativos pelo teste de Wald e os efeitos aleatórios com estimativas de variância diferentes de zero foram incluídos no modelo fenotípico. O hábito de crescimento e dias para maturação absoluta foram considerados como covariáveis na análise. Quanto à escolha dos modelos fenotípicos, o modelo selecionado foi Fator Analítico de Primeira Ordem (FA1) baseado nas diversas estruturas matriciais de VCOV testadas e nos critérios utilizados para seleção. As estimativas dos parâmetros genéticos denotam a variabilidade entre as progênies, possibilitando a obtenção de genótipos com bom desempenho produtivo. Concluiu-se que há grande influência da interação G x E nas estimativas de parâmetros genéticos e fenotípicos associados às características de produtividade e vingamento floral em soja; A resposta correlacionada entre produtividade e vingamento floral foi negativa, inviabilizando a seleção indireta de progênies com alta produtividade e alto número de flores; A seleção baseada em alta produtividade foi satisfatória, destacando-se as progênies P72, P58, P30, T169, T136 e T82.

Palavras-chave: *Glycine max (L.) Merrill*. Estratégias de melhoramento em soja. Interação Genótipo x Ambiente. Vingamento floral. Estruturas reprodutivas.

ABSTRACT

In soybean, potential grain yield is dependent on the number of plants per area, number of pods per plant, number of grains per pod and average grain weight. The contribution of each of these primary production components is variable, however, in some situations the number of pods per plant has been shown to be important. The number of pods depends on the number of flowers produced by the plant and their setting, that is, the proportion of flowers that originate pods. In soybean, normally the number of flowers per plant is much higher than the number of pods, therefore, the floral setting is almost always small. Accordingly, the plant is unable to express all its productive potential, since some stresses (biotic or abiotic) affect flower setting. The objective was to determine the floral setting levels of soybean progenies with different maturity groups; The correlate response for flower set and soybean grain yield; The viability of selection for the floral setting trait. The field experiments were conducted during the 2019/2020 and 2020/2021 crop seasons, in the municipalities of Ijaci, at the Center for Development and Transfer of Technology in Agriculture at UFLA – Palmital Farm, and in the municipality of Lavras, at the Center for Scientific and Technological in Agriculture- Muquém Farm. The F_{2:4} and F_{2:5} progenies were evaluated in two experiments: one containing early progenies and checks and another with late progenies and checks, both conducted under a complete randomized block design (RCBD). The plot consisted of two lines with three meters in length and spacing of 0.5 meters. In the central part, six plants were selected in the first row of each plot, a floral receptacle was placed, aiming to collect reproductive structures that would be aborted. The agronomic traits days for full maturity (DTM), yield (YIELD), growth habit (GROWTH) and flower set (FS) were evaluated. Statistical analyzes were performed in the R environment, using mixed linear models (LMM) and generalized linear models (GLMM). The initial stage of data analysis involved fitting both mixed linear models and generalized linear models to the phenotypic data of each character. Only the fixed effects that were significant according to the Wald test and the random effects with non-zero variance estimates were included in the phenotypic model. Growth habit and days to maturity were taken into consideration as covariates in the analysis. Regarding the choice of phenotypic models, the selected model was a First-Order Analytical Factor (FA1) based on the various VCOV matrix structures tested and the criteria used for selection. Estimates of the genetic parameters denote variability among the progenies, making it possible to obtain genotypes with good yield performance. It was concluded that there is a great influence of the G x E interaction on the estimates of genetic and phenotypic parameters associated with Yield and flower set traits in soybean; The correlated response between the FS and Yield traits is negative, making the indirect selection of progenies with high yield and flower setting unfeasible; The selection based on high productivity was satisfactory, highlighting the progenies P72, P58, P30, T169, T136 and T82.

Key-words: *Glycine max* (L.) Merrill. Soybean breeding strategies. Genotype x Environment interaction. Flower set. Reproductive structures.

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CAPÍTULO 1 INTRODUÇÃO GERAL

1 INTRODUÇÃO

Os caracteres precocidade e produtividade de grãos são amplamente estudados pelos pesquisadores e melhoristas de soja, uma vez que o cenário agrícola brasileiro permite o cultivo de duas safras no mesmo ano. É desejado que as cultivares de soja associem um bom desempenho produtivo e menor maturação absoluta, isto é, sejam precoces para que atendam a demanda atual dos produtores, visando otimizar a segunda safra, e sobretudo diminuir as oscilações climáticas e pressão de patógenos (GESTEIRA *et al.*, 2018).

Neste sentido, um dos grandes desafios para os melhoristas é encontrar estratégias que possam auxiliar no incremento à produtividade de grãos das plantas cultivadas. No caso da soja e outras leguminosas, a produtividade é um caráter que depende de vários fatores bióticos/abióticos e, conseqüentemente, o potencial produtivo das plantas quase nunca é obtido devido aos estresses.

Em soja, a produtividade potencial de grãos é dependente do número de plantas por área, número de vagens por planta, número de grãos por vagem e o peso médio dos grãos. A contribuição de cada um desses componentes primários de produção é variável, contudo, em algumas situações o número de vagens por planta tem se mostrado importante (CARVALHO *et al.*, 2017; PERINI *et al.*, 2012).

O número de vagens é dependente do número de flores produzidas pela planta e o seu vingamento, ou seja, a proporção de flores que originam vagens. Em soja, normalmente o número de flores por planta é muito superior ao de vagens, logo, o vingamento floral quase sempre é pequeno. Por consonância, a planta não tem condições de expressar todo o seu potencial produtivo, visto que alguns estresses (bióticos ou abióticos) afetam o vingamento das flores.

Os efeitos de estresses hídricos durante os estádios fenológicos da cultura da soja, relatados por Sedyama (2015) indicaram que os estádios mais sensíveis são germinação-emergência e florescimento-enchimento de grãos (desenvolvimento das vagens), quando o déficit hídrico pode ocasionar forte queda de flores e vagens.

Estudos desenvolvidos por Ventimiglia *et al.* (1999), Pires *et al.* (2005), Van Schaik e Probst (1958), Hansen e Shibles (1978), Wiebold *et al.* (1981), Peterson *et al.* (1986), Nahar e Ikeda (2002), dentre outros autores, relatam a respeito de estimativas da proporção do vingamento floral em soja. Sabe-se que a cultura da soja tem alta taxa de abortamento floral, e

este alto número de abscisão é consequência dos estresses abióticos e bióticos, além dos fatores fisiológicos e genéticos, e conseqüentemente, o máximo potencial produtivo da cultura da soja nunca é atingido.

É oportuno obter informações a respeito da percentagem do vingamento floral em soja, bem como as correlações entre esse caráter e outros caracteres de interesse para a cultura, visando nortear estratégias para os programas de melhoramento genético da soja em condições tropicais.

2 REFERENCIAL TEÓRICO

2.1 Morfologia e fenologia da planta de soja

A soja é uma planta pertencente ao reino Plantae, divisão Magnoliophyta, classe Magnoliopsida, ordem Fabales, família Fabaceae (Leguminosae), subfamília Faboideae (Papilionoideae), gênero *Glycine*, espécie *Glycine max* e forma cultivada *Glycine max* (L.) Merrill de acordo com Sedyama (2015). Esta possui $2n = 40$ cromossomos (DONG *et al.*, 2004).

A soja é uma planta anual, herbácea, com germinação epígea da semente com porte de ereto à prostrado, autógama, apresentando variabilidade para as características morfológicas, que ainda podem ser influenciadas pelo ambiente, como a altura que pode variar de 30 a 200 cm, apresentando mais ou menos ramificações. Quanto ao ciclo, pode levar de 75 para as mais precoces e 200 dias para as mais tardias (SEDIYAMA; TEIXEIRA; BARROS, 2009).

Possui sistema radicular constituído de raiz axial principal e de raízes secundárias. A radícula do embrião cresce para baixo, dando origem à raiz principal, e, posteriormente, desenvolvem-se nela as ramificações (MÜLLER, 1981). Em suas raízes, a planta de soja apresenta nódulos resultantes da simbiose com bactérias do gênero *Bradyrhizobium*, que têm a capacidade de fixar o nitrogênio do ar presente no solo, reduzindo ou até mesmo dispensando gastos com adubação nitrogenada (MASCARENHAS *et al.*, 2005). O processo de nodulação inicia-se com excreção, pela planta, de compostos que agem como substâncias quimiotáticas e estimulam a multiplicação de bactérias na rizosfera (FINOTO; SEDIYAMA; BARROS, 2009). Fenologicamente, os primeiros nódulos são visíveis nos estádios V1 a V2 (CÂMARA, 1998) e aqueles com o interior róseo, devido à leg-hemoglobina, estão ativos na fixação de N (FINOTO; SEDIYAMA; BARROS, 2009).

O caule é do tipo herbáceo, ereto, pubescente e ramificado, desenvolvendo-se a partir do eixo embrionário, após o início da germinação. Seu crescimento, na maioria das cultivares, é do tipo ortótopo, podendo sofrer influências das condições externas (SEDIYAMA, 2015).

Quanto ao seu hábito de crescimento, as cultivares de soja podem ser de crescimento determinado, semideterminado e indeterminado, que varia de acordo com as características do ápice do caule principal (MUNDSTOCK; THOMAS, 2005; SEDIYAMA, 2015). Cultivares que apresentam hábito de crescimento determinado apresentam inflorescência racemosa terminal e axilar. O florescimento ocorre ao mesmo tempo em toda a planta, que pode atingir aproximadamente 90% da sua altura final antes do florescimento (MUNDSTOCK; THOMAS

2005; BAIGORRI; GASSEN, 2009). O hábito semideterminado apresenta características tanto do tipo determinado quanto do indeterminado. A inflorescência racemosa terminal e axilar está presente; entretanto, na fase do florescimento, as plantas estão com aproximadamente 70% da sua altura final, podendo crescer após a floração (MUNDSTOCK; THOMAS, 2005). As cultivares com hábito de crescimento indeterminado produzem apenas inflorescência axilar, uma vez que a gema terminal apresenta atividade vegetativa, o que faz com que a planta continue emitindo novos nós, alongando o seu caule. O florescimento ocorre de baixo para cima, podendo apresentar vagens bem desenvolvidas no estrato inferior e, ao mesmo tempo, flores no estrato superior (MUNDSTOCK; THOMAS 2005; BAIGORRI; GASSEN, 2009).

As cultivares estão divididas em 13 grupos de maturidade, iniciando-se pelas cultivares mais precoces: 000, 00, 0, I, II, III, IV, V, VI, VII, VIII, IX e X, no hemisfério norte. As cultivares do grupo de maturidade 000 são cultivadas em latitudes maiores, enquanto as do grupo X são cultivadas próximas à linha do Equador (SEDIYAMA, 2016). Dentro de cada grupo de maturidade, podem existir vários ciclos (número de dias entre a semeadura ou a emergência e a maturação plena ou estágio fenológico R8): precoce, semi-precoce, médio, semi-tardio e tardio. Trabalhos realizados no Brasil, por Alliprandini *et al.* (2009), indicaram que predominam cultivares do grupo de maturidade 5,0 a 8,0 para aquelas adaptadas para Região Sul, com ciclo variando entre 106 e 137 dias, já para aquelas adaptadas à Região Centro-Oeste, predominam as do grupo 7,0 a 9,4, com ciclo variando de 108 e 147 dias.

Ao longo do ciclo a soja possui quatro tipos de folhas: as cotiledonares, as simples ou unifolioladas, as compostas ou trifoliadas e os prófilos; todas com tamanho, formato e posicionamentos diferentes (SEDIYAMA, 2015). As folhas de soja variam de verde-claras a verde-escuras, de acordo com a idade, a variedade e os fatores ambientais, especialmente a nutrição nitrogenada e a provisão de ferro (MÜLLER, 1981).

As flores são completas e axilares ou terminais, variando de 2 a 35 por racemo, do tipo papilionada, brancas, amarelas ou violáceas, segundo a cultivar. As flores são consideradas completas por conter órgãos masculino e feminino na mesma estrutura, sendo protegidos pela corola e cálice (NOGUEIRA *et al.*, 2009; SEDIYAMA *et al.*, 2005; SEDIYAMA *et al.*, 1996; SEDIYAMA *et al.*, 1985; SEDIYAMA *et al.*, 1981; MÜLLER, 1981). A abertura floral ocorre geralmente pela manhã e pode ser influenciada pela temperatura e umidade (SEDIYAMA *et al.*, 2005). Gazzoni (2016) afirma que a soja é uma planta autógama, cleistógama e apresenta taxa de polinização cruzada baixa, em níveis médios de 2%, sendo os insetos, especialmente as abelhas, promotores dessa hibridação.

Os frutos, do tipo vagem, são achatados, curtos, de 2 a 7 cm de comprimento, de cor cinzenta, amarelo-palha ou preta e pode chegar ao número de 400 por planta, com número de grãos variando de 1 a 5 por vagem, mas a maioria das cultivares possuem 2 a 3 grãos (FEHR; CAVINESS, 1977; SEDIYAMA *et al.*, 1996; MASCARENHAS *et al.*, 2005; SEDIYAMA; TEIXEIRA; BARROS, 2009; SEDIYAMA, 2015).

As sementes são geralmente elípticas e achatadas, completamente lisas e ligeiramente brilhantes, diferindo quanto à intensidade de seu brilho em razão da presença de ceras na superfície da cutícula. Todavia, existem cultivares que possuem sementes foscas, de cor amarela, verde ou preta. O hilo pode apresentar variação na cor marrom, amarela, marrom-clara, preta imperfeita e preta, no entanto podem ocorrer variações nas tonalidades, em razão da origem genética e das condições de cultivo (SEDIYAMA *et al.*, 1996; SEDIYAMA, 2015).

A soja cultivada [*Glycine max* (L.) Merr.] é considerada uma espécie leguminosa que possui 38%–42% de proteína, 18%–22% de óleo e 4%–6% de sacarose na semente e é comumente adaptada e cultivada em muitas áreas do mundo para consumo humano, ração animal e produção de biodiesel (PATIL *et al.*, 2018).

A fenologia da soja é caracterizada por estádios. Nesta caracterização utilizam-se escalas e a mais adotada na cultura da soja foi desenvolvida por Fehr e Caviness (1977), a qual é dividida em duas fases principais (caracterizadas por diferentes estádios): a fase vegetativa (estádio denominado V) (TABELA 1) e a reprodutiva (estádio denominado R) (TABELA 2). Com exceção dos estádios VE (emergência) e VC (cotilédone), as letras V e R são seguidas de índices numéricos que identificam estádios específicos, nessas duas fases de desenvolvimento da planta. A duração de cada uma delas é controlada geneticamente e influenciada por condições ambientais. A classificação dessas fases é feita com base na observação das folhas e das flores e no desenvolvimento da vagem e da semente que se encontram nos nós da haste principal da planta (NOGUEIRA *et al.*, 2013).

Tabela 1- Descrição resumida dos estádios fenológicos vegetativos da soja.

Estádio	Descrição
V _E	Emergência: os cotilédones estão acima da superfície do solo
V _C	Cotilédone desenvolvido: Cotilédones totalmente abertos
V ₁	Primeiro nó: As folhas unifoliadas estão abertas
V ₂	Segundo nó: Primeira folha trifoliada aberta
V ₃	Terceiro nó: Segunda folha trifoliada aberta
V _(n)	“Enésimo” nó ao longo da haste principal com trifólio aberto

Fonte: Adaptado de Fehr e Caviness (1977).

Tabela 2 - Descrição resumida dos estádios fenológicos reprodutivos da soja.

Estádio	Descrição
R ₁	Início da floração: Uma flor aberta em qualquer nó da haste principal
R ₂	Floração plena: Flor aberta em um dos dois últimos nós da haste principal com folha completamente desenvolvida
R ₃	Início da formação da vagem: Vagem com 5 mm de comprimento em um dos quatro últimos nós superiores com folha completamente desenvolvida, sobre a haste principal
R ₄	Vagem completamente desenvolvida: Vagem com 20 mm de comprimento em um dos quatro últimos nós superiores com folha completamente desenvolvida, sobre a haste principal
R ₅	Início da formação da semente: Semente com 3 mm de comprimento em uma vagem localizada em um dos quatro últimos nós superiores com folha completamente desenvolvida sobre a haste principal
R ₆	Semente completamente desenvolvida: Vagem contendo semente verde, preenchendo a cavidade da vagem localizada em um dos quatro últimos nós superiores com folha completamente desenvolvida sobre a haste principal
R ₇	Início da maturação: Vagem normal sobre a haste principal que tenha atingido a cor da vagem madura
R ₈	Maturação plena: 95% de vagens que tenham atingido a cor da vagem madura. Após R8, são necessários de 5 a 10 dias de tempo seco para que a semente de soja apresente menos de 15% de umidade

Fonte: Adaptado de Fehr e Caviness (1977).

2.2 Fatores ambientais que afetam o florescimento em soja

2.2.1 Altitude

São vários os fatores ambientais que interferem na adaptação de cultivares de soja em todo o Brasil. Essa adaptação é promovida pela alta plasticidade dos genótipos nas diferentes altitudes, latitudes, manejos do solo, população de plantas entre outros (DO CARMO *et al.*, 2018).

De forma geral em altas altitudes ocorrem temperaturas mais amenas, as cultivares apresentam alongamento do ciclo vegetativo, excessivo crescimento da planta, alongamento dos entrenós, abortamento de flores e vagens e acamamento da planta. Regiões de baixas latitudes são caracterizadas por altas temperaturas e déficit hídrico, na qual as cultivares apresentam maturação absoluta menor e adaptação reduzida quando recomendadas a regiões mais altas (BASNET; MADER; NICKELL, 1974; SPADER, 2014).

Sedyama, Teixeira e Barros (2009) verificaram que a altitude influencia no florescimento da soja e conseqüentemente no seu ciclo. Cultivares têm seu ciclo prolongado em temperaturas amenas e altas altitudes (>700m), ou reduzido com temperaturas elevadas em altitudes baixas. De modo geral, ocorre uma relação inversa entre a temperatura média e o ciclo vegetativo, ou seja, temperaturas mais baixas alongam esse período enquanto temperaturas mais elevadas aceleram o florescimento e, conseqüentemente, encurtam o período vegetativo (PASCALE, 1969; FARIAS *et al.*, 2007; EMBRAPA, 2013). Temperaturas médias do ar noturnas ao redor de 24 °C, com fotoperíodo indutivo, induzem o florescimento, enquanto, para cada 0,5 °C, abaixo desse valor, ocorre um alongamento do período vegetativo, entre 2 a 3 dias (WHIGHAM; MINOR, 1978).

2.2.2 Latitude

O sucesso da rápida expansão da soja no Brasil é devido aos esforços dos programas de melhoramento no desenvolvimento de cultivares adaptadas nos diferentes grupos de maturidade relativa existentes.

O cultivo em menores latitudes, abaixo de 30° e/ou próximo à linha do equador ou com semeadura tardia realizada fora da janela de plantio, provoca a redução da fase vegetativa em que compreende o período da emergência da plântula até o início do florescimento (PIPOLO *et al.*, 2002; LEMOS *et al.*, 2011). Isso se dá pelo fato de a soja ser considerada de dias curtos, na

qual nestas regiões o comprimento de horas luz/dia (fotoperíodo) encurta, provocando a redução da fase vegetativa, a diminuição da altura da planta e florescimento precoce resultando na queda de produtividade (MARQUES; ROCHA; HAMAWAKI, 2008).

O tempo compreendido entre a emergência da plântula e o dia em que ela estiver apta a receber o estímulo foral é denominado período juvenil. As plantas de soja podem ser de período juvenil curto e longo. Ao passo que a latitude diminui, a amplitude entre horas de luz e escuro é reduzida, logo para regiões com essas características, por meio de melhoramento genético, introduziu-se genótipos com características de período juvenil longo (SEDIYAMA, 2015).

Diante dessa adversidade com relação ao fotoperíodo, surgiu a necessidade dos programas de melhoramento de soja em desenvolver plantas com período juvenil longo, para permitir o cultivo em latitudes cada vez menores atendendo especificamente regiões promissoras como Centro Oeste e Norte do Brasil.

2.2.3 Temperatura (°C)

A temperatura afeta diretamente na fase de emergência, no período vegetativo que por sua vez determina a época de floração (período reprodutivo), influenciando diretamente no rendimento de grãos. A soja se desenvolve melhor em temperaturas em torno de 30° C, porém, se adapta em regiões que apresentarem temperatura entre 20 e 30 °C (FARIAS; NEPOMUCENO; NEUMAIER, 2007). A temperatura influencia de forma positiva na fase de crescimento (fase vegetativa), pois, atua na fotossíntese (TAIZ; ZEIGER, 2013).

Temperaturas abaixo de 10 C comprometem seu desenvolvimento vegetativo e em regiões com temperatura acima de 40 °C podem chegar a danificar o reprodutivo e na retenção de vagens (FARIAS; NEPOMUCENO; NEUMAIER, 2007). No florescimento em temperaturas acima de 13 °C, somado à soja atingir seu fotoperíodo crítico, a planta receberá estímulos começando a indução floral ou fase reprodutiva. Em condições de mesma época de semeadura ao percorrer dos anos, a mesma cultivar apresenta diferentes datas de florescimento devido à variação anual de temperatura. Em casos de alta temperatura o florescimento é acentuadamente precoce, podendo provocar a redução da altura da planta e em baixas temperaturas o florescimento é retardado podendo provocar maior crescimento vegetativo (FARIAS; NEPOMUCENO; NEUMAIER, 2007). A temperatura também afeta a produção e rendimento de grãos juntamente com precipitação ou atuando de forma isolada (CHEN; WIATRACK, 2010).

Segundo Pascale (1969), existe uma relação inversa entre a temperatura média e o número de dias necessários para a floração (RODRIGUES *et al.*, 2001). Dessa forma, temperaturas mais baixas causam aumento no período para que ocorra o florescimento. Parker e Borthwick (1943) observaram que a indução floral foi ótima quando a temperatura nas folhas estava entre 21 e 27 °C à noite, e que acima dos 27 °C poucos primórdios florais foram formados.

Temperaturas abaixo de 21 °C, ou acima de 32 °C, podem reduzir o florescimento e o estabelecimento das vagens. As temperaturas elevadas podem ser uma das causas do abortamento de flores em soja (NOGUEIRA, 1983).

2.2.4 Umidade

A planta de soja tem exigências hídricas que aumentam progressivamente com o desenvolvimento da cultura. A demanda é máxima no florescimento e início de formação de legumes, mantendo-se alta até a maturação fisiológica (SEDIYAMA, 2015).

A água atua como solvente universal, constituindo 90% do peso da planta atuando em quase todos os processos fisiológicos e bioquímicos. Participa ainda no transporte de minerais e gases no interior das células (CASAGRANDE *et al.*, 2001). Os mesmos autores destacam que a falta de água pode provocar efeitos na produção que são dependentes da época de ocorrência nas fases da cultura e da severidade. A falta de água no florescimento causa o aborto das flores, impedimento da antese floral, afeta o desenvolvimento de grãos e conseqüentemente o rendimento de grãos.

Assim, a precipitação é um dos elementos meteorológicos de grande importância para a cultura da soja, sendo que sua ausência ou excesso, dependendo da fase fenológica na qual ocorra, poderá implicar em prejuízos tanto no acúmulo de matéria seca quando na produtividade e qualidade dos grãos (HUNTER; ERICKSON, 1952; SIONIT; KRAMER, 1977).

A cultura tem demanda hídrica crescente atingindo o máximo na fase de enchimento de grãos e início de formação dos legumes estendendo até a maturação fisiológica. A falta de água pode alterar a produção de massa pela planta, podendo interferir na relação entre o período vegetativo e reprodutivo (MUNDSTOCK; THOMAS, 2005). Em trabalho realizado por Casagrande *et al.* (2001), os autores relatam que a umidade é indispensável para o bom crescimento e desenvolvimento da planta de soja para atingir bons índices de produtividade. A baixa umidade pode afetar na absorção de água, germinação de sementes, fechamento de

estômatos, a transpiração, a fotossíntese, na atividade enzimática (FARIAS; NEUMAIER; NEPOMUCENO, 1995).

A necessidade de água pela soja vai aumentando conforme a planta vai crescendo, atingindo o ponto máximo durante o enchimento de grãos, chegando a aproximadamente 8 mm de água por dia. Déficits hídricos expressivos quando ocorridos durante o florescimento ou enchimento de grãos provocam grandes prejuízos à produtividade devido ao fechamento estomático, enrolamento de folhas que reduzem a taxa fotossintética e a produção de biomassa (RITCHIE, 1998).

Para se obter altos rendimentos na produção é necessária uma boa distribuição de chuvas, principalmente nas fases de maior demanda de água, como no florescimento com um consumo diário de 7 a 8 mm, coincidindo na fase reprodutiva com maior altura da planta e área foliar (FARIAS; NEPOMUCENO; NEUMAIER, 2007).

A necessidade total de água na cultura da soja, para obtenção do máximo rendimento, varia entre 450 e 800 mm/ciclo, dependendo das condições climáticas, do manejo da cultura e da duração do ciclo da cultivar (EMBRAPA, 2010).

2.2.5 Fotoperíodo

O fotoperíodo é definido como duração, em horas, do comprimento do dia mais os crepúsculos (CHANG, 1974).

A cultura da soja é uma das espécies cultivadas mais sensíveis ao fotoperíodo, sendo este o regulador de desenvolvimento vegetal mais importante para a cultura, pois de acordo com o fotoperíodo a planta pode ser ou não induzida ao florescimento. Esta sensibilidade é atribuída de forma que cada cultivar possui seu fotoperíodo crítico, acima do florescimento retardado, sendo considerada uma cultura de dias curtos (DA SILVA *et al.*, 2017). Além do crescimento, o fotoperíodo afeta a maturação, altura de planta, peso das sementes, número de ramificações, vagens por planta (BARROS; SEDIYAMA, 2009).

Sediyama, Teixeira e Barros (2009) descrevem que para ocorrer à indução floral é necessário que a quantidade de luz recebida pela planta seja menor ou igual a um denominado fotoperíodo crítico máximo.

O fotoperíodo crítico é o número de horas de luz menor ou máximo capaz de induzir uma planta ao florescimento desde que este esteja apta à percepção da variação do comprimento do dia. Cada genótipo possui um fotoperíodo crítico, diferindo assim as interferências no início

do florescimento, podendo ser classificadas em cultivares de período juvenil curto e longo (FARIAS; NEPOMUCENO; NEUMAIER, 2007).

O tema fotoperíodo é de extrema importância para os estudos em soja, porque a indução ao florescimento está diretamente relacionada com o comprimento do dia, ou mais especificamente, com o comprimento da noite, em razão do acúmulo do fitocromo P660 (SEDIYAMA, 2015).

A taxa de desenvolvimento da soja também é impactada pelo fotoperíodo devido ao seu comportamento de plantas de dias curtos. O fotoperíodo regula o início do florescimento (GARNER; ALLARD, 1920; HADLEY *et al.*, 1984; CAFFARO *et al.*, 1988) e a duração das fases fenológicas (RAPER; THOMAS, 1978; KANTOLIC; SLAFER, 2001; NICO; MIRALLES; KANTOLIC, 2015).

O fitocromo é o pigmento responsável por desencadear o processo de indução floral. Ele absorve radiação dentro das faixas do vermelho e do vermelho distante, apresentando alternadamente duas estruturas distintas, simbolizadas por P660 e P730. Na presença da radiação solar, o fitocromo converte-se de P660 a P730, acumulando-se nesta forma. Na ausência de luz, reverte-se o processo e acumula-se na forma de P660. Assim, na condição de dias longos, a forma P730 acumula-se por longo tempo, o que induz plantas de dias longos ao florescimento e suprime o florescimento de plantas de dias curtos. Ao contrário, na condição de dias curtos, a forma P660 se acumula por um longo tempo, induzindo plantas de dias curtos a florescer e inibindo o florescimento de plantas de dias longos. Então, na verdade, a duração do período escuro é a responsável por desencadear o processo de indução ao florescimento em plantas sensíveis (SEDIYAMA, 2015).

O subperíodo vegetativo pode ser definido como pré-indutivo ou juvenil. Nesse período, entre a emergência e a primeira folha verdadeira (estádio V1) as plantas de soja são incapazes de perceber estímulo ao fotoperíodo. A partir daí, dependendo do genótipo, a planta adquire a capacidade de perceber os estímulos (maturação), que induzem as transformações de seus meristemas vegetativos em reprodutivos (fase indutiva) (RODRIGUES *et al.*, 2001).

Um aumento na duração do dia acima de um determinado limite, principalmente relacionado ao grupo de maturidade (McBLAIN; BERNARD, 1987; XIA *et al.*, 2012; LU *et al.*, 2017), pode retardar o processo de desenvolvimento. Esta característica tem um impacto particular na fase pós-floração, que é mais sensível ao fotoperíodo nas cultivares tardias do que nas precoces (MAJOR *et al.*, 1975; KANTOLIC; SLAFER, 2001). O tipo de crescimento (determinado vs. indeterminado) também resulta em diferentes respostas ao fotoperíodo, principalmente entre o início do florescimento (R1) e início do enchimento das sementes (R5),

onde o número final de nós é fixo para cultivares indeterminadas. Para essas cultivares, fotoperíodos longos aumentarão a duração da fase R1 a R5 (PIPER *et al.*, 1996; HAN *et al.*, 2006; KANTOLIC *et al.*, 2013).

A expansão da soja é restrita pela sensibilidade dos genótipos ao fotoperíodo para uma maior adaptação e para explorar seus altos níveis de produtividade. Com a descoberta do período juvenil longo e sua introdução nas cultivares melhoradas, estas, comportam-se com amplo aspecto de adaptabilidade podendo ser cultivadas em baixas latitudes, possibilitando aumentar a janela de plantio (RAY *et al.*, 1995; FARIAS; NEPOMUCENO; NEUMAIER, 2007). O fotoperíodo e a temperatura estão intimamente relacionados com o período da indução floral na soja e são estudadas por meio de relação quantitativas (MAJOR *et al.*, 1975; HODGES; FRENCH, 1985; SINCLAIR *et al.*, 1991; RODRIGUES *et al.*, 2001). Entretanto, Silva *et al.* (2017), destacam que, apesar do controle genético do florescimento ser atribuído a poucos genes, o fotoperíodo e a temperatura afetam o ciclo bem como o florescimento, tendo uma distribuição contínua, mas não quantitativa.

2.3 Vingamento floral

O desenvolvimento reprodutivo em culturas de grãos é iniciado pela floração, onde o número de frutos e sementes que serão produzidos é determinado durante este período. A produção de flores e sementes é considerada uma fase chave para definir os componentes de produção de uma cultura (EGLI, 2005).

Na soja o florescimento pode se dar de três maneiras dependendo do seu tipo de crescimento, podendo ser determinado, semideterminado ou indeterminado. Essa classificação tem como base a presença e a posição da inflorescência racemosa, podendo ser axilar ou axilar e terminal (NOGUEIRA *et al.*, 2009; SEDIYAMA, 2015). Os do tipo de crescimento determinado essencialmente completam seu ciclo vegetativo pouco antes da floração em áreas de melhor adaptação. A haste principal termina com uma inflorescência racemosa e, geralmente, as últimas folhas apresentam similaridade (de forma e tamanho) com as demais. Os do tipo de crescimento semideterminado continuam diferenciando o número de nós da haste principal, por certo período; todavia cessa seu crescimento com uma inflorescência racemosa terminal. Já aqueles de crescimento indeterminado continuam a aumentar sua altura por um período relativamente longo, após iniciado o florescimento. Sua altura frequentemente dobra depois do aparecimento da primeira flor (SEDIYAMA, 2015). Segundo Nogueira *et al.* (2009), a maturação das plantas de tipo de crescimento determinado e semideterminado ocorre de cima

para baixo; enquanto as de tipo de crescimento indeterminado, a maturação ocorre de baixo para cima.

Em soja, assim como em outras culturas, o rendimento de sementes é um caractere complexo, que depende de muitas variáveis (MALIK *et al.*, 2007). O número de vagens por planta e sementes por vagem são os principais determinantes do rendimento em soja (NAVARRO JUNIOR; COSTA, 2002; KANTOLIC; PERALTA; SLAFER, 2013). Muitos fatores podem influenciar a produção e manutenção das estruturas reprodutivas em soja, e uma estratégia seria buscar aumento na produtividade pela diminuição do aborto de flores e abscisão dos legumes, proporcionando que mais legumes cheguem a fase final de maturação (PIRES *et al.*, 2005).

O número de flores é diretamente relacionado ao número de nós, embora haja evidências de que as condições ambientais podem influenciar o número de flores nó; o número de nós por planta é influenciado pelas condições ambientais durante o período de crescimento vegetativo ou pelo ciclo de maturação da cultivar (CARRETERO, 2011).

A abscisão é o processo em que ocorre a perda de órgãos ou tecidos. Várias plantas podem abortar frutos e flores, como parte de um programa de desenvolvimento ou de uma forma de resposta a estímulos como estresse abiótico ou biótico (EGLI, 2005). O aborto precoce das estruturas reprodutivas da soja foi inicialmente reconhecido por Woodworth (1932). Aumentos substanciais na produtividade da soja poderiam ser alcançados se a abscisão de flores e vagens pudesse ser reduzida ou evitada. Segundo Peterson, Williams e Kuang (1990), o conjunto de vagens pode variar muito com base na cultivar, data de plantio e fatores de estresse ambiental.

Van Schaik e Probst (1958) relataram que a abscisão das flores de soja começou 5 dias após a abertura da primeira flor, com o percentual final de abscisão variando de 43% a 81% do número total de flores e vagens formadas. Hansen e Shibles (1978) observaram uma taxa de abscisão de 63% para duas variedades do centro-oeste dos Estados Unidos, enquanto Wiebold, Ashley e Boerma (1981) observaram uma taxa de abscisão de 67% a 82% entre os genótipos avaliados. Peterson *et al.* (1986) relataram uma média de 79% de abscisão floral para a cultivar da variedade Bragg, com mais de 75% dessas abscisões ocorrendo durante um período de 14 dias a partir do momento que a floração atingiu o seu pico. Estudos conduzidos por Nahar e Ikeda (2002) mostraram que a taxa de abscisão floral pode variar de 60 a 92% em soja, logo o vingamento floral é baixo, e o potencial produtivo da planta nem sempre é atingido. A ocorrência da grande produção de flores pela soja e sua capacidade de produzi-las mesmo após iniciado o processo de enchimento de grãos determinam a existência de um elevado potencial reprodutivo da cultura. Contudo, este potencial não é refletido no rendimento final da cultura,

devido à abscisão de grande porcentagem (DYBING, 1994). Apesar do abortamento de botões florais ou de flores ser um evento que ocorra naturalmente na maioria das plantas, principalmente no final do período reprodutivo, quando o número máximo de órgãos reprodutivos que pode ser sustentado já foi estabelecido, a intensidade dessas perdas pode ser influenciada pelo genótipo e por condições ambientais (MONTERROSO; WIEN, 1990).

A fixação de grãos é determinada pelo número de óvulos por flor, pela frequência de embriões abortados e pelo número de vagens por planta (TISCHNER *et al.*, 2003). O baixo nível de fertilidade em algumas espécies ocorre em função do abortamento programado geneticamente em embriões jovens (WIENS, 1984). De acordo com Tanksley (1993), o número de óvulos e o abortamento de embriões são exemplos de características quantitativas resultantes da interação entre o genótipo e o ambiente de cultivo.

Estudos anatômicos do desenvolvimento de flores em plantas leguminosas comprovam que a fixação de flores varia em função da posição em que ela se encontra no racemo da planta, sendo que as flores próximas ao racemo apresentam maior probabilidade de desenvolvimento do que flores de posições distais (HUFF; DYBING, 1980; BRUN; BETTS, 1984; PETERSON *et al.*, 1984).

Wiebold e Panciera (1990) observaram que o desenvolvimento vascular, tanto do floema quanto do xilema é variável em função do tempo e da posição das flores na planta, sendo que quando distantes da planta ou do racemo a vascularização é menor e menores serão as chances de desenvolvimento.

A vascularização, idade e posição de flores nas leguminosas tem efeito sobre a fixação de estruturas reprodutivas, tanto fatores fisiológicos quanto anatômicos tem influência no desenvolvimento ou não dessas estruturas. Quando a quantidade de vagens em início de desenvolvimento se aproxima do potencial máximo de suprimento pela planta, a competição entre drenos é determinante para a ocorrência de falhas no desenvolvimento de flores emitidas tardiamente (FIOREZE, 2013).

A redução do abortamento pode resultar no aumento do número de vagens e sementes, e assim conduzir a um acréscimo na produtividade de grãos (NONOKAWA *et al.*, 2012).

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CAPÍTULO 2 SIMULTANEOUS SELECTION FOR FLOWERING SET AND AGRONOMIC TRAITS IN SOYBEAN BREEDING

ABSTRACT

In soybean, potential yield is dependent on the number of plants per area, number of pods per plant, number of grains per pod and average grain weight. The contribution of each of these primary production components is variable, however, in some situations the number of pods per plant has been shown to be important. The number of pods depends on the number of flowers produced by the plant and on the flower set, that is, the fertilized flowers that originate pods. It is known that, as a result of biotic, abiotic, physiological and genetic factors, the soybean crop has a high rate of floral abscission. The objective was to determine the floral setting levels of soybean progenies with different maturity groups; The correlated response between flower set and soybean grain yield; The viability of selection for the floral setting trait. The field experiments were conducted during the 2019/2020 and 2020/2021 crop seasons, in the municipalities of Ijaci, at the Center for Development and Transfer of Technology in Agriculture at UFLA – Palmital Farm, and in the municipality of Lavras, at the Center for Scientific and Technological in Agriculture- Muquém Farm. The F_{2:4} and F_{2:5} progenies were evaluated in two experiments: one containing early progenies and checks and another with late progenies and checks, both conducted under a complete randomized block design (RCBD). The plot consisted of two lines with three meters in length and spacing of 0.5 meters. In the central part, six plants were selected in the first row of each plot, a floral receptacle was placed, aiming to collect reproductive structures that would be aborted. The agronomic traits days for full maturity (DTM), yield (YIELD), growth habit (GROWTH) and flower set (FS) were evaluated. Statistical analyzes were performed in the R environment, using mixed linear models (LMM) and generalized linear models (GLMM). Estimates of the genetic parameters denote variability among the progenies, making it possible to obtain genotypes with good yield performance. It was concluded that there is a great influence of the G x E interaction on the estimates of genetic and phenotypic parameters associated with Yield and flower set traits in soybean; The correlated response between the FS and Yield traits is negative, making the indirect selection of progenies with high yield and flower setting unfeasible; The selection based on high productivity was satisfactory, highlighting the progenies P72, P58, P30, T169, T136 and T82.

Key words: *Glycine max* (L.) Merrill. Soybean breeding. Flower set. Yield. Reproductive structures.

1 INTRODUCTION

Soybean plants produce a large quantity of flowers. However, under field conditions, the potential of seeds production frequently is limited by a failure of flower set or pod set or by pod drop (PETERSON; WILLIAMS, KUANG, 1990; VENTIMIGLIA *et al.*, 1999; VAN SCHAİK; PROBST, 1958, WIEBOLD; ASHLEY; BOERMA, 1981; HANSEN; SHIBLES, 1978; DALL'AGNOL, 1981). A large number of factors participate and interact to determine the yield of a soybean crop, among which could be highlighted the meteorological and crop management. In case of soybean, even in the best growing conditions abscission of flowers and pods occurs (MARCHEZAN, 1982).

Abscission of flowers and young pods becomes evident at the time of fertilization and during proembryo development (ABERNETHY *et al.*, 1977; DALRYMPLE, 1979; CARLSON; LERSTEN, 2004; KATO, 1964). The number of flowers is directly related to the number of nodes, although there is evidence that environmental conditions can influence the number of node flowers; the number of nodes per plant is influenced by environmental conditions during the vegetative growth period or by the maturation group of the cultivar (CARRETERO, 2011). Pandey and Torrie (1973) demonstrated that pod number and number of seeds per pod had the greatest influence on soybean yield. The number of flowers per node seems to correlate positively with flower abscission. The most frequent time of abortion of the flower or pod is about 1 to 7 days after flowering (CALDWELL; HOWELL, 1973).

Van Schaik and Probst (1958) reported that soybean flower abscission began 5 days after the opening of the first flower, with the final percentage of abscission ranging from 43% to 81% of the total number of flowers and pods formed. Hansen and Shibles (1978) observed an abscission rate of 63% for two varieties from the Midwest of the United States, while Wiebold, Ashley e Boerma (1981) observed an abscission rate of 67% to 82% among the evaluated genotypes. Bredan *et al.* (1978) reported total abscission of 54 and 57% for one cultivar grown in the field and greenhouse, respectively. Peterson *et al.* (1986) reported an average of 79% floral abscission for the cultivar Bragg, with more than 75% of these abscissions occurring during a 14-day period from the time when flowering reached its peak. Studies conducted by Nahar and Ikeda (2002) showed that the floral abscission rate can vary from 60 to 92% in soybean, so the floral set is low, and the productive potential of the plant is not always reached.

The main factors involved in the fixation of soybean flowers and pods are the availability of nutrients and assimilates destined for these reproductive structures, when in

development, as well as the availability of some phytohormones (NAGEL *et al.*, 2001). Inflorescences and pods during their developmental stages require sufficient hormones, nutrients and assimilates throughout the entire developmental period until they reach maturity. In soybean, as in other leguminous species, vegetative growth lasts until the intermediate or final stage of the reproductive period, varying according to the growth habit of the cultivar.

Therefore, strong competition for assimilates and nutrients between plant organs can lead to a deficiency of these for the reproductive structures. Insufficient supply of photoassimilates to developing flowers and pods is a determining factor in the abortion of these reproductive structures (NONOKAWA *et al.*, 2012; PASSOS *et al.*, 2011). Many environmental factors have been reported to influence the rate of flower and pod abortion. Temperature extremes, low radiation intensities, and water stress increased the rate of flower and pod abortion (SHAW; LAING, 1966; MANN; JAWORSKI, 1970; SAITO *et al.*, 1970). Casagrande *et al.* (2001) mention that the lack of water at flowering causes the abortion of flowers, impediment of floral anthesis, and affects the development of grains and consequently the grain yield.

Flower production profiles are influenced by the environment (ZHENG *et al.*, 2002) and growth habit (GAI; PALMER; FEHR, 1984). The position of developing flowers or pods on the rachis of individual racemes has also been shown to influence pod set or abscission. In a small group of cultivars, distal flowers have been reported to set less fruit than proximal ones (HUFF; DYBING, 1980; BRUN; BETTS, 1984; PETERSON *et al.*, 1984). These reports and the previously cited observations that more mature or first formed pods on a raceme may inhibit or retard growth of later formed flowers or pods suggest that intraraceme competition may be contributing to the processes controlling flower and pod set of soybean (PETERSON; WILLIAMS; KUANG, 1990).

Although abiotic factors exert a great influence on yield, it should not be ruled out that soybean grain yield depends on intrinsic factors of the genotype, such as: growth habit, number of pods, seed characteristics and cycle. The number of pods retained by soybean plant communities is an important yield determinant and, perhaps, the yield might be increased by reducing reproductive abscission. However, little information is available that describes the abscission levels and patterns for modern cultivars and in addition, most of the studies carried out used few cultivars. Genetic variability is needed before selection for reduced abscission is possible. This study stands out for its originality, since in the recent literature no studies were found in Brazil carrying out similar experiments, considering flower set in soybean progenies from different maturity groups as well as different growth habits. With this, the importance of

deepening the theme was supported, since Brazil occupies a very important space on the world stage with regard to the production of the grain.

This study was conducted to determine flower set levels for different soybean progenies with different maturity groups. It was also sought to verify if there is a correlation between the floral setting in soybean and yield, as well as whether it is possible to make a selection for the trait floral setting.

2 MATERIAL AND METHODS

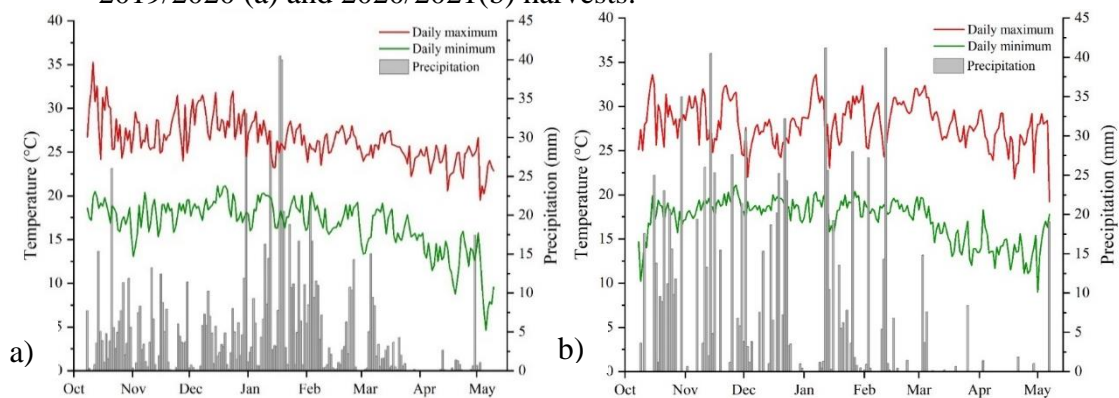
2.1 Experimental environments

The study was carried out in two locations, at the cities of Lavras-MG and Ijaci-MG, during the 2019/2020 and 2020/2021 seasons.

- In the region of Lavras-MG, at the Center for Scientific and Technological Development in Agriculture - Muquém Farm, located at latitude 21°14' S, longitude 45°00' W and altitude of 918 m.
- In the region of Ijaci-MG, at the Center for Scientific and Technological Development in Agriculture – Palmital Farm, located at latitude 21°09' S, longitude 44°54' W and altitude of 920 m.

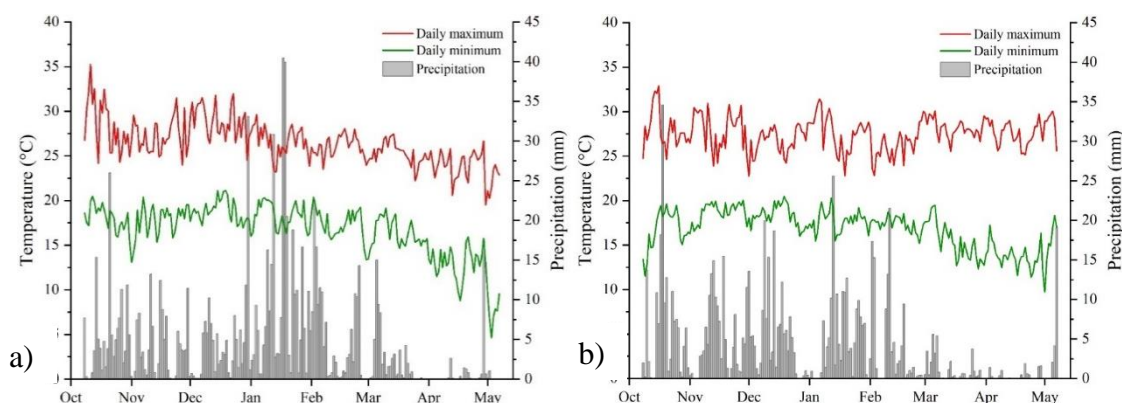
The climatological data of the experimental environments are presented in Figure 1 and 2 as follows:

Figure 1 - Precipitation, maximum and minimum temperature, in the city of Lavras/MG, in the 2019/2020 (a) and 2020/2021 (b) harvests.



Source: NASA (2022).

Figure 2 - Precipitation, maximum and minimum temperature, in the city of Ijací/MG, in the 2019/2020(a) e 2020/2021(b) harvests.



Source: NASA (2022).

2.2 Progeny and population development

In order to create segregating populations, three parent plants were utilized: FMT 2, FMT 3, and BRS 780 RR. The FMT 2 and FMT 3 lines were provided by Fundação Mato Grosso (Fundação MT) and are characterized by their indeterminate growth habit, early maturity cycle, and potentially high yield performance. BRS 780 RR, on the other hand, was developed by *Brazilian Agricultural Research Corporation* - EMBRAPA and has a relative maturity group 7.8, making it suitable for the REC-MG 303, Triângulo Mineiro and Alto Paranaíba edaphoclimatic regions. This cultivar has a determined growth habit with a medium to late maturity cycle, resistance to cyst nematodes, and moderate resistance to soybean rust. All three parent plants were pure and contrasting, exhibiting excellent agronomic performance. To develop the populations, three parents were intercrossed, two by two plant:

- a) FMT3x BRS 780 RR (Population 1)
- b) FMT2 x BRS 780 RR (Population 2)

The two crosses were carried out in a greenhouse in the 2016/2017 harvest. Manual hybridization was performed in the crossing block and a procedure similar to that described by Borém *et al.* (2009) was adopted. The F₁ seeds were advanced in the 2017 winter nursery under a greenhouse, adopting two plants per pot. The F₂ population was generated during the summer season of 2017/2018. The plot was arranged in a four-line pattern with a length of 5 meters each and a sowing density of 15 seeds per meter.

At physiological maturity, individual plants were pulled-harvested in order to obtain F_{2:3} progenies from the same genetic background. Individual plants were pulled on two dates,

February 24th, 2018 and March 9th, 2018 corresponding to the group of early and late progenies, respectively. The plants were individually threshed using hand threshing. The F_{2:3} progenies were cultivated in Lavras and Ijaci, Minas Gerais state, during the 2018/2019 summer crop season in order to increase the number of seeds in the progenies.

2.3 Installation and conduction of experiments

For all evaluated environments, the no-tillage system was adopted, with sowing furrows spaced at 0.50 m. The sowing of the F_{2:4} and F_{2:5} progenies was carried out in the first half of November at Lavras (2019/2020 and 2020/2021 crop seasons) and in the second half of November at Ijaci (2019/2020 and 2020/2021 crop seasons).

Fertilization was carried out via furrow using 350 Kg. ha⁻¹ of the formulated N-P₂O₅-K₂O (02-30-20). The inoculation, via the sowing furrow, was carried out at the time of sowing, using *Bradyrhizobium japonicum* bacteria in the form of a liquid inoculant at a dose of 18 mL p. c. kg⁻¹ of seed – SEMIA 5079 and 5080 strains, containing 10.8x10⁶ CFU/seeds of the inoculant Nitragin Cell Tech HC® (3x10⁹ CFU/mL), the volume of spray applied was equivalent to 150 L. ha⁻¹. The opening of the furrows was performed mechanically by the seeder and sowing was done manually.

For pest control, insecticides with active ingredient Neonicotinoid, Pyrethroid and Chlorpyrifos were used, the applications being conditioned to the need for pest control. Weed control in post-emergence was carried out using glyphosate at a dosage of 2 L.ha⁻¹. The other cultural treatments were performed according to the procedure presented by Soares *et al.* (2020).

The progenies were evaluated in two experiments: one containing early maturity progenies and one with late cycle progenies. The checks used in the two crop seasons (2019/2020 and 2020/2021), for both experiments containing early progenies and for the experiments containing late progenies, are shown in Table 1.

Table 1 - Soybean cultivars used as checks and their respective information on maturity group, growth habit and company that maintains the genetic material.

Cultivar	Maturity group	Growth habit	Company
P95R51	5.5	Inderminate	Pioneer
M5917	5.9	Indeterminate	Monsoy
ANTA 82	7.3	Semi-determinate	TMG
DESAFIO	7.4	Inderteminate	Brasmax
98Y12	8.1	Determinate	Pioneer
M8210	8.2	Determinate	Monsoy
TMG 2185	8.5	Determinate	TMG

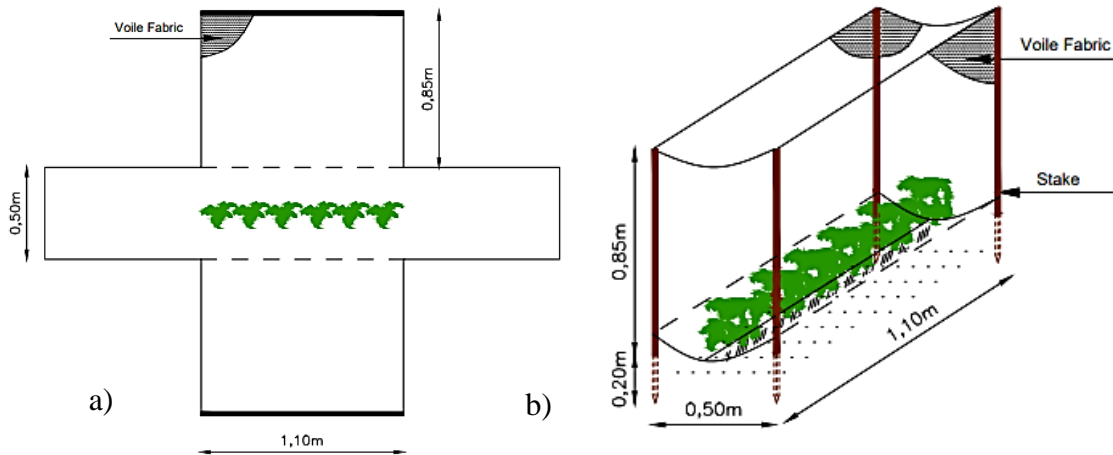
Source: From the author (2023).

In the 2019/2020 season, the experiment with early progenies was arranged as a randomized complete block design (RCBD), with three replications, with 90 treatments (78 progenies + 7 controls + 6 inert genotypes), totaling 270 plots per location. The experiment with late progenies was also carried out under a RCBD with three replications, with 90 treatments (84 progenies + 7 controls), also totaling 270 plots per location.

For the 2020/2021 season, selection was carried out within the two groups (early and late progenies), using as a criterion the genotype presenting desirable agronomic traits. The experiment on early progenies included 43 progenies, and a selection process with an intensity of 55% was carried out. The experiments were allocated containing 43 progenies + 6 checks, totaling 49 treatments, under a RCBD with three replications, totaling 147 plots. A selection process was conducted on the group of late progenies with an intensity of 51%, resulting in a total of 43 progenies. The experiment was composed of 43 progenies + 6 checks (total 49 treatments) arranged as a RCBD with three replications (total of 147 plots)

Each plot consisted of two rows of 3.0 meters spaced at 0.5 meters, with three replications and the sowing density was adjusted according to the maturity group of the progenies. In order to make it possible to count aborted reproductive structures, floral receptacles were constructed (FIGURE 3).

Figure 3 - Floral abscission collection receptacle: a) Top view of receptacle showing construction before assembling sides and ends. b) Assembled and anchored with voile fabric fitted around enclosed plants.



Source: From the author (2023).

The construction of the floral receptacle and collection of aborted flowers followed a methodology similar to that described by Izquierdo and Hosfield (1981). The floral receptacle was built in the plot when the plants reached the V5 stage (FEHR; CAVINESS, 1977). Floral receptacles were built and placed on the central part of the first row of each plot, comprising the six central plants of the row. This receptacle had a dimension of 1.10 m long, 0.50 m wide and 0.85 m high. As a covering, a white voile fabric was used, so that it was in a “U” shape. To make the receptacle, wooden stakes 1.05 m long were used in order to support the voile fabric. The lower end of the fabric was cut, and the plants were placed inside the receptacle. The receptacle was then carefully sewn up to envelop the 6 plants within the useful area of the plot, ensuring that there were no holes that could result in the loss of the aborted structures. The plants completed their cycle within the structure (APPENDIX, FIGURE 1A).

The collections started about 10 days after the flowering of the first plot of each experiment and were repeated every three days. In each receptacle, all material was carefully collected and the presence of reproductive structures containing the ovary (flower buds, flowers, pods in all stages of grain filling) was observed (APPENDIX, FIGURE 1B). For the evaluation of floral setting, 6 plants were used from the central part of the first row of each plot, and two replications.

The plots were harvested in the field at the R8 stage (FEHR; CAVINESS, 1977). To calculate the yield, all plants in the plot were harvested. To determine the number of pods per plant and other associated characteristics, the plants that were inside the floral receptacle were

used. After the mechanical threshing, the seeds were separated from the impurities, with the aid of sieves, being identified and packed in paper bags. Seeds with high moisture content were exposed to the sun until they reached a content of 13%, suitable for storage.

Evaluated traits:

- a) Full maturity: 90% of the plants in the plot at stage R8 (days);
- b) Number of pods per plant (X): it was evaluated at the time of harvest, where the number of pods inside the receptacle, obtained from the 6 existing plants, was recorded;
- c) Number of total flowers (N): obtained by adding the number of aborted flowers and the number of pods;
- d) Percentage of floral setting (FS): obtained by the estimator:

$$FS = \frac{X}{N} * 100 \quad (1)$$

Where:

X= number of pods per plant

N= total number of flowers.

- a) Yield (YIELD): determined based on the harvest of all plants in the plot. After standardizing the grain moisture to 13%, yield was defined, in Kg.ha⁻¹, from the conversion of the area of each plot;
- b) Growth habit (GROWTH): classified as determinate, semi-determinate or indeterminate according to Bernard (1972), using a visual scale;
- c) Relative maturity group (RM): standard checks were used, that is, the most stable cultivars for the region (SILVA *et al.*, 2022; ALLIPRANDINI *et al.*, 2009). The standard checks were P95R51 (5.5), M5917 (5.9), DESAFIO RR (7.4), 98Y12 (8.1), ANTA82 (7.3), TMG2185 (8.5) and M8210 (8.2). Thus, it was possible to obtain the RM of the progenies through the first-degree regression equation:

$$Y = \beta_0 + \beta_1 X \quad (2)$$

Where:

Y: Relative maturity

β_0 : Intercept

β_1 : Coefficient of slope of the line

X: Absolute maturity in days

2.4 Statistical analysis

The data were analyzed via the linear mixed models (LMM) approach using the ASReml package (BUTLER *et al.*, 2017) implemented in R (R CORE TEAM, 2018).

The statistical model was as follows:

$$\mathbf{y} = \mu \mathbf{1}_n + \mathbf{X}_1 \mathbf{t} + \mathbf{X}_2 \mathbf{b} + \mathbf{X}_3 \mathbf{b} \cdot \mathbf{t} + \mathbf{X}_4 \mathbf{r} \cdot \mathbf{s} + \mathbf{X}_5 \mathbf{g}_1 \cdot \mathbf{s} + \mathbf{Z}_1 \mathbf{g}_2 \cdot \mathbf{s} + \mathbf{e} \quad (3)$$

where \mathbf{y} is an $n \times 1$ vector of observations for i progenies across s trials, where $n = \sum_{i=1}^s n_i$, in which n_i is the number of plots in trial s ; μ is the overall mean; \mathbf{t} is an $s \times 1$ vector of the fixed effects of trials; \mathbf{b} is a $q \times 1$ vector of the fixed effects of sets; $\mathbf{b} \cdot \mathbf{t}$ is a $(qs \times 1)$ vector of the fixed effects of the interaction between sets and trials; $\mathbf{r} \cdot \mathbf{s}$ is a $(jqs \times 1)$ vector of the fixed effects of replicates within sets within trials; $\mathbf{g}_1 \cdot \mathbf{s}$ is a $ks \times 1$ vector of the fixed effects of check lines, $\mathbf{g}_2 \cdot \mathbf{s}$ is an $ms \times 1$ vector of the random effects of progenies within set, with $\mathbf{g}_2 \cdot \mathbf{s} \sim \text{MVN}(\mathbf{0}, \mathbf{G} \otimes \mathbf{I}_m)$; and \mathbf{e} is an $n \times 1$ vector of residuals, with $\mathbf{e} \sim \text{MVN}(\mathbf{0}, \bigoplus_{i=1}^s \mathbf{D}_{e_i} \otimes \mathbf{I}_{n_i})$. \mathbf{G} is a VCOV matrix for the effect of progenies across trials with dimensions $s \times s$. An FA structure of order k , where k is the number of multiplicative components (FA_k) was considered to model \mathbf{G} . \mathbf{D}_{e_i} is an $s \times s$ diagonal VCOV matrix, in which each trial has specific and independent variance components for the effects for the residuals. The Kronecker product is denoted by \otimes . $\mathbf{X}_1, \mathbf{X}_2, \mathbf{X}_3, \mathbf{X}_4, \mathbf{X}_5$, and \mathbf{Z}_1 represent incidence matrices for their respective effects, with dimensions $n \times s, n \times q, n \times qs, n \times jqs, n \times ks$, and $n \times ms$, respectively; $\mathbf{1}_n$ is an $n \times 1$ vector of 1s (ones); and \mathbf{I}_m and \mathbf{I}_{n_i} are identity matrices of their corresponding orders.

From the variance components, heritability estimates were obtained for all evaluated traits. Non-significant fixed effects were removed from the final model at a significance level of 5%, considering the Wald test. The random effects associated with genetic and residual effects were performed based on the Akaike criterion – Akaike Information Criterion – AIC (AKAIKE, 1974).

For each trait, from the selected model, the predicted values of the genotypic values of the progenies by environment (locations x harvests) and the average of the environments were obtained, allowing ordering them according to their performance for each character and overall.

The floral setting character was analyzed with a mixed generalized linear model (GLMM), similar to the model [3], but with a binomial distribution family and the logit link function. In this case, the number of pods divided by the total number of flowers was considered

the response variable. Because of the complexity of fitting a GLMM, no attempt was made to model the different residuals for each trial. Thus, the residuals were assumed as $e \sim \text{MVN}(\mathbf{0}, \mathbf{R} \otimes \mathbf{I}_{n_i})$, where \mathbf{R} is a VCOV matrix for the effect of the Residuals across trials with dimension $s \times s$.

The coefficient of variation (CV) was estimated by:

$$CV = \frac{\sqrt{\sigma_E^2}}{\bar{X}} \times 100 \quad (4)$$

Where:

CV : coefficient of experimental variation expressed in percentage;

σ_E^2 : residual variance;

\bar{X} : overall phenotypic mean.

Experimental precision was measured by estimating the experimental variation coefficient (CV) and selective accuracy ($r_{\hat{g}g}$) (RESENDE; DUARTE, 2007).

The selective accuracy was determined by the following estimator (GEZAN; MUNOZ, 2014).

$$r_{\hat{g}g} = \sqrt{1 - \left(\frac{PEV}{\sigma_G^2} \right)} \times 100 \quad (5)$$

Where:

$r_{\hat{g}g}$: selective accuracy expressed as a percentage;

PEV : variance of the prediction error of the predicted values;

σ_G^2 : genotypic variance.

Estimates of heritabilities (h^2) at the progeny level for each experiment were obtained as follows:

$$h^2 = \frac{\sigma_G^2}{\sigma_G^2 + \frac{\sigma_E^2}{r}} \times 100 \quad (6)$$

Where:

h^2 : is the heritability, at the progeny level, expressed in percentage;

σ_G^2 : is the genetic variance component;

σ_E^2 : is the residual variance component;

r : is the number of replications.

Estimates of the expected gain with selection (EG) were obtained for the characters evaluated, considering selection proportions of 15%. The expected gains from selection will be estimated by:

$$EG = \frac{\overline{Pred Value_{j/i}}}{\bar{Y}_j} \times 100 \quad (7)$$

Where:

EG : expected gain with the selection expressed in percentage;

$\overline{Pred Value_{j/i}}$: average of predicted values of progenies;

\bar{Y}_j : general average of the progenies in generation i or in all generations.

The realized gain (RG) was estimated for 15% of selection proportion already mentioned. For each character, the genotypes with the best predicted values in generation i were selected and their average in generation j was verified. Estimates of realized gain were obtained by the estimator:

$$RG = \frac{Pred Value_{j/i}}{\bar{Y}_j} \times 100 \quad (8)$$

on what:

RG : realized gain expressed in percentage;

$Pred Value_{j/i}$: average of the predicted values of the progenies in generation j by the selection made in generation i ;

\bar{Y}_j : general average of progenies in generation j .

For the estimates of the correlated response (CR), the following estimator was used:

$$CR_y = b_{(a)yx} R_x \quad (9)$$

where:

CR_y : correlated response in y ;

R_x : direct response;

$b_{(a)yx}$: regression of the genetic value of y on the genetic value of x

3 RESULTS AND DISCUSSION

3.1 Adjustment of phenotypic models

The initial stage of data analysis involves fitting both mixed linear models and generalized linear models to the phenotypic data of each character. Only the fixed effects that were significant according to the Wald test and the random effects with non-zero variance estimates were included in the phenotypic model. Growth habit and days to maturity were taken into consideration as covariates in the analysis, even when it was not significant. It is important to note that a two-step process was followed: first, the fixed effects were tested, and then the random effects were added after identifying the significant fixed effects. Finally, the variance components and trait heritability were estimated for the selected random effects in the final phenotypic model for the character under evaluation.

Regarding the choice of phenotypic models, the selected model was a First-Order Analytical Factor (FA1) based on the various VCOV matrix structures tested and the criteria used for selection. The analytical factor model has been widely recommended in plant breeding research (PIEPHO, 1998; BURGUEÑO *et al.*, 2012; CULLIS *et al.*, 2014; SMITH *et al.*, 2015; DIAS *et al.*, 2018). This model accurately depicts the interaction between genotypes and environments, addressing the heterogeneous variances between experiments and enabling the calculation of genetic relationships between different environments. The model captures the behavior variations of genotypes within each environment and across environments (KELLY *et al.*, 2007).

The analysis of flower set (FS) data involved an evaluation of the fixed effects using the Wald test. The results showed that the main effects of Environment, Experiment, Growth Habit, Days to maturity, Check within genotype, Block within Environment and the interaction between Environment and Experiment were all found to be significant ($p < 0.001$) (TABLE 3).

Regarding the Yield, a Wald test was conducted to examine the fixed effects. The results indicated that the main effects of Environment, Experiment, Block within Environment, Check within genotype, and the interaction between Environment and Experiment were all significant ($p < 0.001$). However, the effect of Days to maturity and Growth habit was not significant (TABLE 3).

The key conclusions that can be drawn from the results discussed above for the floral setting character are: one or more controls displayed a significantly different behavior in terms of FS compared to the others, at least one of the genotypes exhibited significantly different

values of FS for different Days to maturity, one or more of the locations, blocks, growth, and experiments showed a significantly different flower setting compared to the others, and there was a differing response to the Environment within Experiment and/or vice versa and to the Block within Environment and/or vice versa (TABLE 3). It can be observed that: at least one check behaved significantly different from the others in terms of Yield variable, at least one of the locations, one of the blocks and one of the Experiments presented Yield significantly different from the others and there was a different behavior of Environment within Experiment and/or vice versa and to the Block within Environment and/or vice versa. It seems that the experiments in the studied environments displayed a lack of agreement.

There were significant differences for the progeny effect for the evaluated traits, suggesting that there is genetic variability for these traits and opportunities for improvement through selective breeding. These differences may have been influenced by the different levels of homozygosity, as each generation advancement, the same progeny generates varying levels of segregation, resulting in genetic diversity (BARBOSA-PRESTES *et al.*, 2008) (TABLE 3).

From a plant breeding perspective, it is crucial to determine the impact of the environment on the studied traits. This is because the phenotype of each genetic treatment is not only influenced by the genetic effect but also by the environmental effect and the interaction between genotype and environment (G x E), represented by the Environment x Experiment effect in this study. Given the quantitative nature of the genetic control of the evaluated traits, the Environment x Experiment component was significant for all characters (TABLE 3). Yield and maturity traits are known to be highly susceptible to environmental factors (RAMALHO *et al.*, 2012; LEITE *et al.*, 2015), which explains why yield and floral setting traits were greatly influenced by the environment and experiment in this research.

Table 3 - Wald test for Yield (Yield) and floral setting (FS) traits referring to the evaluation of F_{2:4} and F_{2:5} progenies, in the 2019/2020 and 2020/2021 seasons, in the municipalities of Ijaci and Lavras- MG.

Effect	DF	FS	Yield
Environment	3	3129.0**	618.9**
Experiment	1	209.9**	14.8**
Growth	1	14.6**	0.0 ^{ns}
Days to maturity	1	68.6**	0.0 ^{ns}
Environment: Experiment	3	36.3**	135.2**
Environment: Block	16	426.2**	320.3**
Check: Genotype	6	367.6**	144.3**

^{ns}, **, * Wald test not significant and significant at 1% and 5% respectively, by Chi Test Square.
Source: From the author (2023).

3.2 Genetic parameters

Estimates of the genetic and phenotypic parameters for the evaluated characters Yield and Flower Set (FS) referring to the joint analysis of early and late F_{2:4} and F_{2:5} progenies, in the four evaluated environments (Lavras and Ijaci in the 2019/2020 and 2020/2021 seasons) by the Restricted Maximum Likelihood Method (REML) are presented in Table 4.

Field-level experiments in plant breeding programs aim to identify significant differences, select superior genotypes and/or discard less promising genotypes. In this sense, it is essential that the experiments are conducted with high precision, thus allowing accurate inferences and reliable estimates for proper discrimination of genotypes and decision-making (CARGNELUTTI FILHO *et al.*, 2012).

Selective accuracy is one of the most relevant parameters for evaluating the quality of an experiment in plant genetic improvement programs, since it also depends on the proportion between genetic and residual variations associated with the trait under evaluation (RESENDE; DUARTE, 2007).

For the Yield variable, the accuracy estimates were considered high for the two environments studied in the 2019/2020 season, being 79.56% in the Ijaci site and 88.15% in the Lavras. In the 2020/2021 harvest, the accuracy was 6.32% at the Ijaci site and 43.70% at the Lavras site (TABLE 4), the first being considered low and the second low precision according to Resende and Duarte (2007), which indicates a low precision of the experimental 2020/2021 season when compared to the previous season (TABLE 4).

According to Resende and Duarte (2007), estimates of selective accuracy (rgg') can be considered high precision when greater than 70%, medium precision from 30% to 70%, and low precision when less than 30%.

Regarding the Flower Set (FS) variable, the accuracy estimates obtained in the 2019/2020 season were 25.88% for the Ijaci site and 31.46% for the Lavras site, which are classified as low and medium, respectively. In the 20/21 harvest, accuracy estimates of 31.78% were observed at the Ijaci site and 43.70% at the Lavras site, both classified as averages according to Resende and Duarte (2007) (TABLES 4 and 5).

Both Yield and Flower Set variables, values lower than 70% of accuracy can be explained by the fact that both characters are quantitative in nature, highly influenced by the environment and complex inheritance (BREVEDAN *et al.*, 1978). The Flower Set can be considered the most susceptible to external effects as it is highly influenced by numerous environmental effects and sampling errors, since the count is performed manually.

Climate data revealed that the maximum and minimum average temperatures varied between years, within each location, as well as differences between locations. In the city of Ijaci, during the 2019/2020 crop season, there were heavy rains concentrated between January and February, which causes cloudier days with low light. From March the rains significantly decreased, with periods of drought in April. Regarding temperatures, a significant drop in average minimum and maximum temperatures was observed from April onwards (FIGURE 2a).

The 2020/2021 season experienced less rainfall, which was distributed from November to March, with a dry spell in January. From mid-March to April and May, there was a period of intense drought and a noticeable drop in minimum temperatures (FIGURE 2b). This dry spell, which coincided with the reproductive stage and grain filling phase, could have had a direct impact on the results for that season.

During the 2019/2020 season in the city of Lavras (FIGURE 1a), the water regime and the maximum and minimum average temperatures were similar to those in the city of Ijaci (FIGURE 2a). There were very heavy rains concentrated between January and February and a period of drought from the end of March to April. However, during the 2020/2021 season in Lavras (FIGURE 1b), there were differences compared to the Ijaci city (FIGURE 2b). The rainfall was not well distributed, with some heavy downpours (over 40 mm) occurring from November to May. The cities of Lavras and Ijaci showed different weather patterns during the 2020/2021 season. In Lavras, there were some instances of heavy rainfall in the period between November and May, but the distribution of rainfall was not consistent.

On the other hand, Ijaci experienced a dry spell in January, with high average maximum temperatures and little rainfall. During the 2019/2020 season, however, the water regime and maximum and minimum average temperatures were similar in both cities, with heavy rainfall concentrated between January and February and a period of drought from the end of March to April. The average minimum temperature in Lavras also dropped significantly in mid-April.

The growth and development of soybean plants are affected by temperature and the amount of water they receive. Optimal temperatures for soybean growth are between 20°C and 30°C. Low temperatures can impede growth, while high temperatures can reduce growth rate, disrupt flowering, and cause abortion of flowers, pods, and grains. The soybean crop requires a total of 450 mm to 800 mm of water per cycle, with the greatest need for water during the flowering and grain-filling phase. A poor distribution of precipitation, especially during the reproductive phase, can significantly reduce crop yield and cause abortion for both flowers and pods.

The temperatures in both Lavras and Ijaci were suitable for soybean cultivation, which is reflected in the yields achieved (TABLE 1A), which were above the national average (CONAB, 2023). The rainfall distribution was similar in both cities, with the highest volumes of precipitation occurring in November, December, January, and February. However, both cities also experienced a dry spell in January 2021, which may have impacted the crop yield for that season. All these observations on temperature, rainfall, dry spells, show some of the numerous environmental factors that contributed to the highly significant G x E interaction (TABLE 4).

The use of models that allow the inclusion of fixed and random effects allows estimating the variance components and the genetic parameters that are important for the knowledge of the genetic control of the traits of interest in a breeding program, as well as the heritability of the character and the gain with selection. Estimates of genotypic variance were significant for Yield and FS, demonstrating the existence of differences between the progenies within the different experiments (early and late) in relation to these characters (TABLE 4).

The existence of genotypic variance ($\hat{\sigma}_G^2$) is an important estimate to verify the existence of variability among progenies. It is observed that in the 2019/2020 season, the genotypic variance points to the existence of variation for the Yield, enabling selection (TABLE 4).

This occurrence can be attributed to the genetic makeup, as the offspring are derived from multiparental populations with high genetic variance and high frequency of favorable

alleles for traits of agronomic interest. It should be noted that the existence of genetic variability is essential for the success of plant breeding programs because the selection of superior individuals is more effective when done on heritable variations (BERNARDO, 2010; RAMALHO *et al.*, 2012).

The residual variance was higher than the genotypic variance in both evaluated locations during the 2019/2020 and 2020/2021 season for the Yield. This suggests that non-genetic factors play a significant role in affecting this trait, and the low genotypic variance can be attributed to the selection process for more productive genotypes, which has reduced the variability among progenies.

Similarly, the FS showed a similar pattern with regard to variance results. In all environments studied, the residual variance was greater than the genotypic variance, indicating that this trait is heavily influenced by external factors, as previous research has noted (VAN SCHAİK; PROBST, 1958; SHIBLES; SECOR; FORD, 1987; FARIAS *et al.*, 2007; BOARD; KAHLON, 2011; SCHAPAUGH; ROOZEBOOM, 2012).

In general, the FS trait showed little expressive genotypic variance values, and these were overcome by the residual variance in all studied environments, revealing that the genetic control of this trait is not predominantly genetic, making it difficult to obtain gains with selection, which in turn have a low proportion.

Heritability estimates are an indication of success for the breeder, as the greater their effect, the greater the proportion of observed variation that will be transmitted to offspring, the proportion of total variation that is due to genetic rather than environmental causes.

Cruz and Regazzi (1997) mentioned that complex characters commonly have low heritability, while less complex characters have higher estimates of this parameter. Thus, the low values of the heritability estimates for the Yield and FS traits obtained in this study, in most of the evaluated environments, show that most of the observed phenotypic variation cannot be attributed to differences at the genotypic level (TABLE 4).

For the Yield, the heritability estimates varied among the environments studied. In the 2019/2020 season, heritabilities of 77.7% and 63.3% were obtained at the Lavras and Ijaci locations, respectively, corroborating the existence of genetic variability for the character (TABLE 4).

According to the classification described by Resende (2002), heritability can be considered as of low magnitude when $h^2 < 0.15$, medium magnitude between $0.15 < h^2 < 0.50$ and high magnitude with $h^2 > 0.50$. Based on this information, it can be seen that the heritability estimates for the Yield trait in the 2019/2020 season at the Lavras and Ijaci locations were

considered of high magnitude (TABLE 4), revealing that the genetic control of this trait was predominantly genetic at this location and agricultural year, thus making it possible to obtain gains from selection. In relation to the 2020/2021 season, the heritability estimates for this trait decreased drastically, showing values of 29.2% in the Lavras site and 0.4% in Ijaci and classified as medium and low magnitude, respectively (RESENDE, 2002), corroborating the results obtained for the genotypic variance of the trait. Lower heritability values are usually related to complex traits, controlled by several genes (BUENO *et al.*, 2013).

Regarding the FS trait, both heritability estimates found in the two locations studied in the 2019/2020 season were considered of low magnitude ($h^2= 6.7\%$ in Ijaci and 9.9% in Lavras). In the following season, the values for this parameter increased, but not very significantly ($h^2= 10.1\%$ in Ijaci and 19.1% in Lavras), being classified as low and medium magnitudes, respectively (RESENDE, 2002) (TABLE 4).

It is important to point out that the values of heritability and selective accuracy decrease in the direction of the complexity of each character evaluated, which was already expected, since more complex characters both involve a greater number of genes for determination as well as suffer a greater influence of the effect environmental. Among these, the lowest values of heritability and accuracy were for the Flower Set, in the 19/20I environment, with values of 6.7% and 25.88% , respectively. These results corroborate those found by Xavier and Rainey (2020) who, in a study using the SoyNAM population, determined that the number of pods had low heritability.

For the Yield in the 2020/2021 season, both in Lavras and Ijaci, the heritability and, consequently, the accuracy, were low, which can be explained by the residual variance that increased significantly compared to the previous season (2019/2020). Another explanation is the fact that a selection of approximately 50% was carried out between the progenies within the two experiments (early and late progenies) at the end of the 20/21 season, considerably reducing the genetic variance between the progenies (TABLE 4).

Table 4 - Estimates of genetic and phenotypic parameters of early and late F_{2:4} and F_{2:5} progenies for grain yield (Yield) and Flower Set (FS) in the four studied environments.

Parameter	Environment							
	19/20I		19/20L		20/21I		20/21L	
	Yield	FS	Yield	FS	Yield	FS	Yield	FS
$\hat{\sigma}_G^2$	190496.8	0.05920889	559011.1	0.09070126	6526.5	0.09236708	98663.3	0.19474213
$\hat{\sigma}_E^2$	530818.0	3.289868	766850.5	3.289868	750045.0	3.289868	1148587.1	3.289868
σ_{Yield}^2	3954.1	-	4596.9	-	5394.6	-	3783.6	-
σ_{FS}^2	-	2.0612577	-	2.0311109	-	1.0452894	-	0.8822038
h^2 (%)	63.3	6.7	77.7	9.9	0.4	10.1	29.2	19.1
r_{gg} (%)	79.56	25.88	88.15	31.46	6.32	31.78	54.01	43,70

$\hat{\sigma}_G^2$: genetic variance; $\hat{\sigma}_E^2$: residual variance; h^2 : heritability (%); r_{gg} : accuracy (%); 19/20I and 19/20L: season 19/20 at Lavras and Ijaci locations, respectively; 20/21I e 20/21L: season 20/21 at Lavras and Ijaci locations, respectively.

Source: From the author (2023).

The joint estimates of the maximum, minimum, average values and ranges of variation of the evaluated characters, as well as the frequency distributions, are presented in Table 5 and Figure 2, respectively. The predicted values obtained by the joint analysis for the early and late progenies are shown in Table 1a.

The ranges of variation of the means were 1,288 kg.ha⁻¹ and 18% for yield and floral setting, respectively. The lowest yield average among the early progenies, 3.734 kg.ha⁻¹, corresponds to the P14 progeny, while among the late progenies the lowest average productivity was 3.700 kg.ha⁻¹, corresponding to the T140 progeny (TABLE 1, FIGURE 3). It should be noted that all evaluated progenies performed better than the Brazilian average of 3.029 kg.ha⁻¹ (Table 1A) (CONAB, 2022).

Levels of reproductive failure ranging from 26 to 81% have been documented (VAN SCHAİK; PROBST, 1958; KATO, 1964; HANSEN; SHIBLES, 1978; WIEBOLD *et al.*, 1981; PETERSON *et al.*, 1986; JIANG; EGLI, 1993). In this study, the averages obtained for the floral setting (FS) ranged from 68% to 86% (TABLE 5), that is, with values from 14% to 32% of abortion, with most of the evaluated progenies presenting a setting above 70%.

Abortion and abscission can occur at several stages of reproductive development with both flowers (KATO; SAKAGUCHI; NAITO, 1955, VAN SCHAİK; PROBST 1958, HUFF; DYBING, 1980, HEITHOLT; EGLI; LEGGETT, 1986) and immature pods (HANSEN; SHIBLES, 1978, McBLAIN; HUME, 1981) reported to be the most vulnerable to reproductive failure.

Table 5 - Joint estimates of the maximum and minimum predicted values and range of variation of the Yield (kg.ha⁻¹) and Flower Set (FS) characters. Data referring to early and late F_{2:4} and F_{2:5} progenies in the four environments studied.

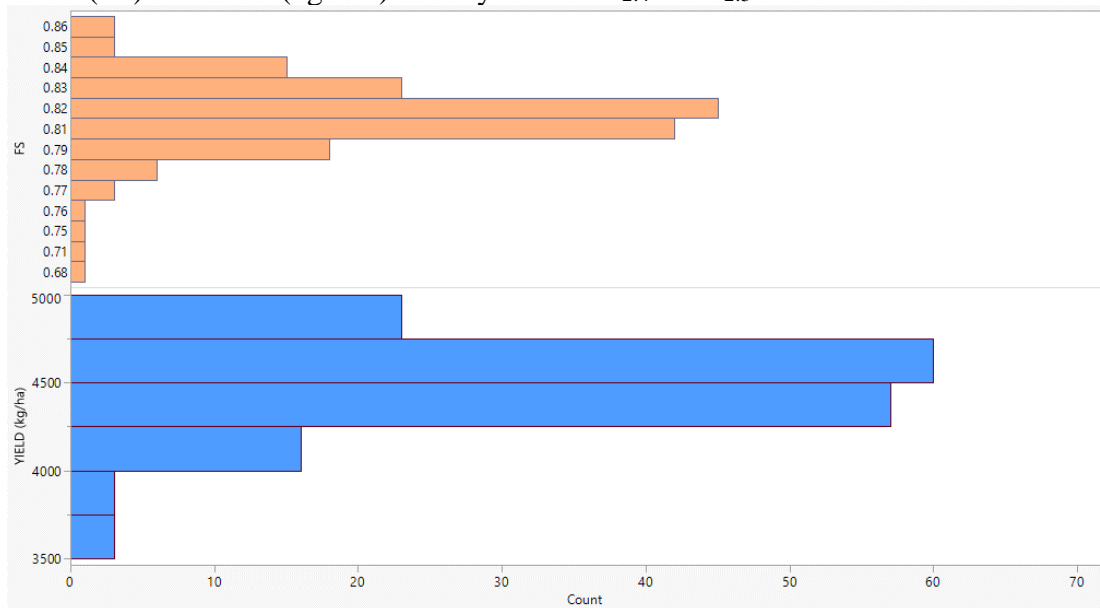
	Yield	FS
Maximum	4988	86.0
Minimum	3700	68.0
Average	4484	81.2
Amplitude	1288	19.5

Source: From the author (2023).

As well as the estimates of the variance components, the frequency distributions of the predicted mean values show the variability between the progenies and denote the quantitative nature of the traits due to the continuous distribution (FIGURE 4).

The results of this study revealed that around 70% of the evaluated progenies had yield ranging from 4000 to 4750 kg ha⁻¹, indicating a high productive potential among the genotypes under examination. Despite the fact that previous research has highlighted the high rate of floral abscission in soybeans, which can reach levels as high as 90%, it is important to note that the cultivars used in these studies should not be compared to contemporary cultivars, as they have undergone plant breeding programs aimed at enhancing their performance. It was observed that both, early and late progenies, had a high percentage of flower set, with values above 60% (TABLE 5, FIGURE 4, TABLE 1A), which can be explained by the fact that soybean breeding programs in Brazil have been working intensively to select soybean cultivars with high yield (SEDIYAMA; MATSUO; BOREM, 2021). One of the soybean yield components is the total number of pods, which has a significant linear correlation with grain yield (FERRARI *et al.*, 2018). The results for yield in this study were found to be higher than the national average, indicating that the floral setting may have a high percentage of yield as shown in Table 1A.

Figure 4 - Frequency distribution for the predicted mean values for the characters Flower Set (FS) and Yield (kg.ha⁻¹) of early and late F_{2:4} and F_{2:5} in the four environments studied



Source: From the author (2023).

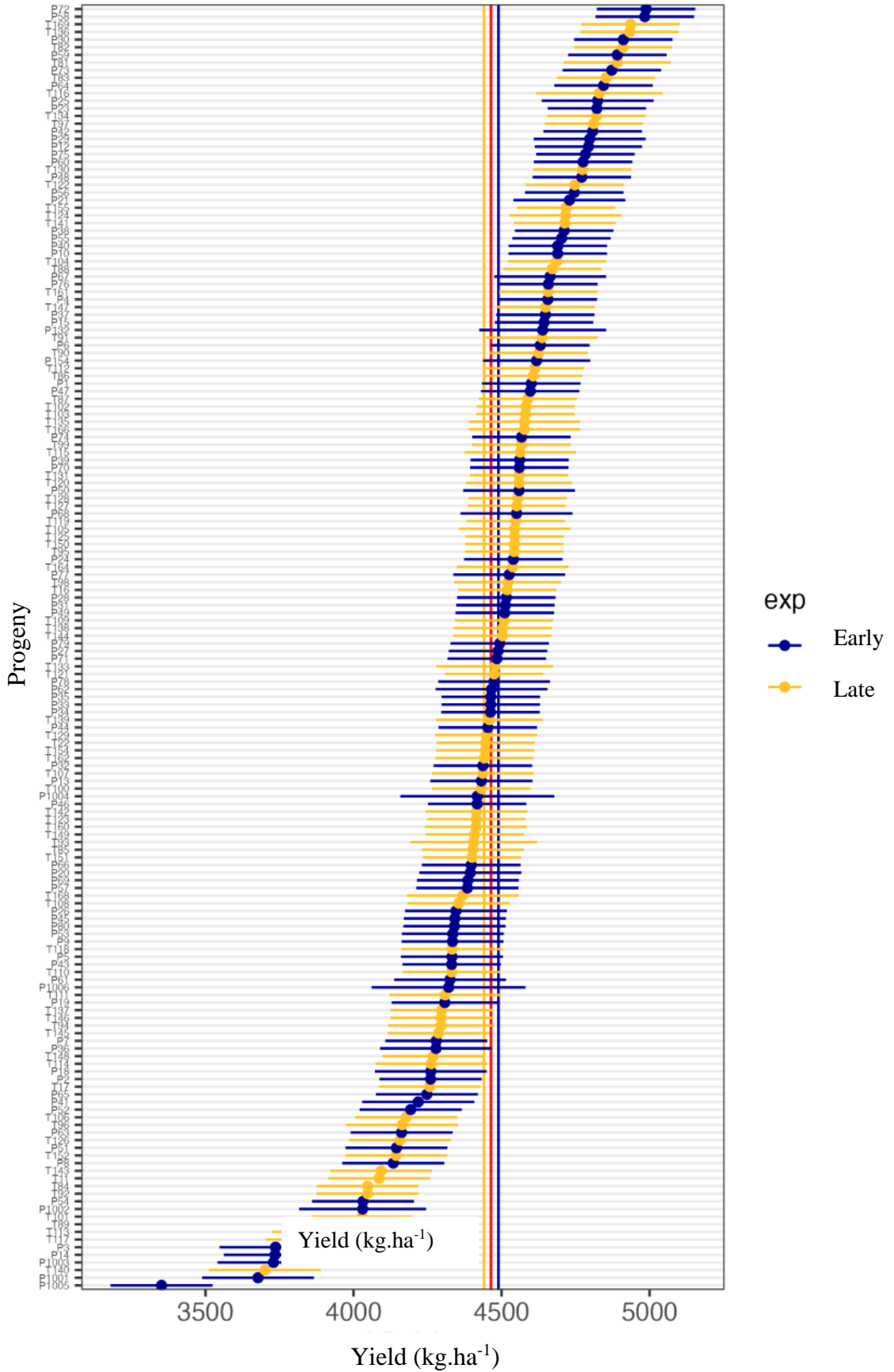
Figure 5 showed the standard deviation and the average predicted Yield values for the evaluated early and late progenies, where the blue dots represent the average predicted values for the early progenies and the yellow dots for the late progenies. The yellow, blue and red lines represent the means of late and early progenies and the general mean of all evaluated progenies, respectively.

It is noticed that early progenies had a greater number of individuals with values above the general average ($4484 \text{ kg}\cdot\text{ha}^{-1}$). The overall average of the Yield for early progenies was $4489 \text{ kg}\cdot\text{ha}^{-1}$, surpassing late progenies, with an overall average of $4440 \text{ kg}\cdot\text{ha}^{-1}$, contrary results were reported by Gesteira *et al.* (2015); Pereira *et al.* (2016); Ribeiro (2018) and Martins (2021) who mentioned that late progenies are superior to early ones. The lower performance, in terms of Yield, of late progenies when compared to early progenies can be attributed to the existence of environmental adversities such as pests, diseases and excess or lack of rain, as well as a greater exposure of these progenies to these effects, as they have longer cycle.

During the 2020/2021 harvest, there was a dry spell, in the two locations evaluated, during the month of January (FIGURE 1b and 2b). This time, considering the planting date of the trials, coincided with a critical phase in the soybean crop, the beginning of the reproductive period (R1) (FEHR; CAVINESS, 1977). It is also noted that, in all environments studied, rainfall became scarce between the end of February and the beginning of March, coinciding with relatively high temperatures and wide thermal amplitude (FIGURE 1a and b; FIGURE 2a and b). This factor may have interfered with the yield of the progenies, especially those of the late cycle, since it coincides with the soybean grain filling period and low water availability in this phase can lead to lower grain weight and, consequently, lower yield (FARIAS; NEPOMUCENO; NEUMAIER, 2007).

According to Stefanova and Buirchelll (2010), when one considers that the objective of the analysis is the selection of the genotypes with the best performances, based on their classification, assuming the effects of genotypes as random and the consequent use of BLUP is justified, as these maximize the correlation between the estimates obtained for the values of random effects and the true values of cultivation and use of the evaluated genotypes (FIGURE 5; FIGURE 1A).

Figure 5 - Graphical representation of the predicted average values for the Yield (kg.ha⁻¹) of early and late F_{2:4} and F_{2:5} progenies in the four environments studied.



Source: From the author (2023).

Figure 6 showed the standard deviation and the predicted mean values of Flower Set for the evaluated early and late progenies, where the blue dots represent the predicted mean values of early progenies and the yellow dots of late progenies. The yellow, blue and red lines represent the means of the late progenies, the means of the early progenies and the general mean of all evaluated progenies, respectively.

It is observed that late progenies had a greater number of individuals with values above the general average for the character Floral Set (81%) (FIGURE 6). The overall character mean for late progenies was 84.2%, surpassing early progenies, with a general mean of 79.1%.

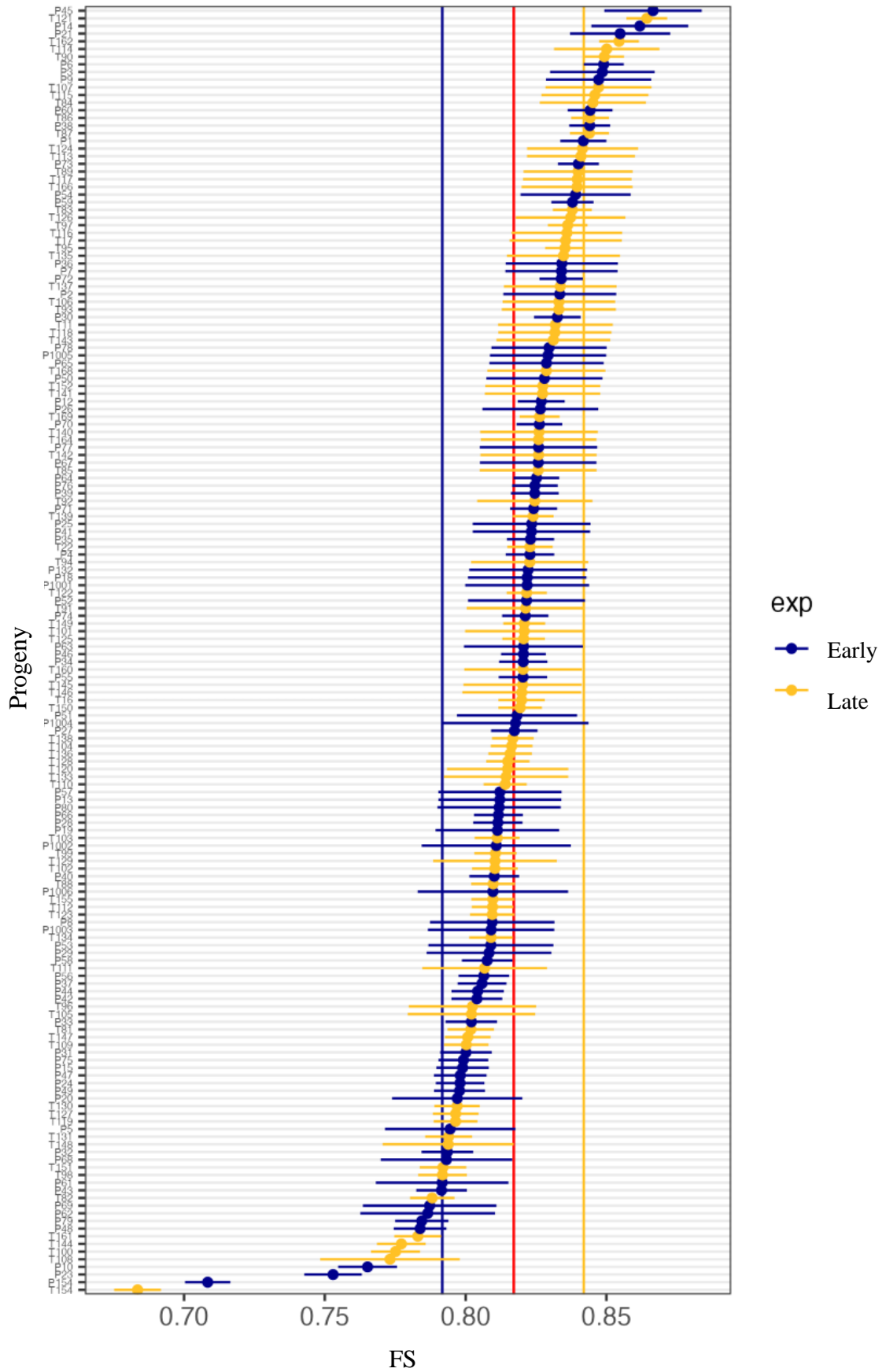
Among the early progenies evaluated, the ones that presented the highest flower set were the P45 and P14 genotypes with 86% and 86%, Yield of 4342 kg.ha⁻¹ and 3734 kg.ha⁻¹ and relative maturation of 7.2 and 7.4, respectively (FIGURE 6 ; TABLE 1A).

In relation to the late progenies, those that presented the highest Flower Set were T121 and T162 with Flower Set of 86% and 85%, Yield of 4474 kg.ha⁻¹ and 4441 kg.ha⁻¹ and relative maturation of 7.1 and 7.8, respectively (FIGURE 6; TABLE 1A). This result contradicts from those found by Gai, Palmer and Fehr (1984), where the later maturity cultivars (and more flowers) had the lower percentage of pod set.

According to the same authors, late-maturing cultivars of both the determinate and indeterminate types produced many more than did early maturing cultivars, so the chance of success is greater for plants that produce a large number of flowers than for those that produce a small number, since floral setting is highly influenced by numerous environmental factors already mentioned above. This result indicates that the number of pods among progenies was much more stable than the number of flowers (GAI; PALMER; FEHR, 1984).

The results obtained emphasize the assertion that soybean has strong reproductive plasticity, in part due to the overlap of pod formation, seed set, and seed filling periods (VOGEL *et al.*, 2020), since early progenies with lower floral set had productive performance greater when compared to late progenies, with high flower set (TABLE 1A).

Figure 6 - Graphical representation of the predicted mean values for the Flower Set (FS) of the early and late $F_{2:4}$ and $F_{2:5}$ progenies in the four environments studied.



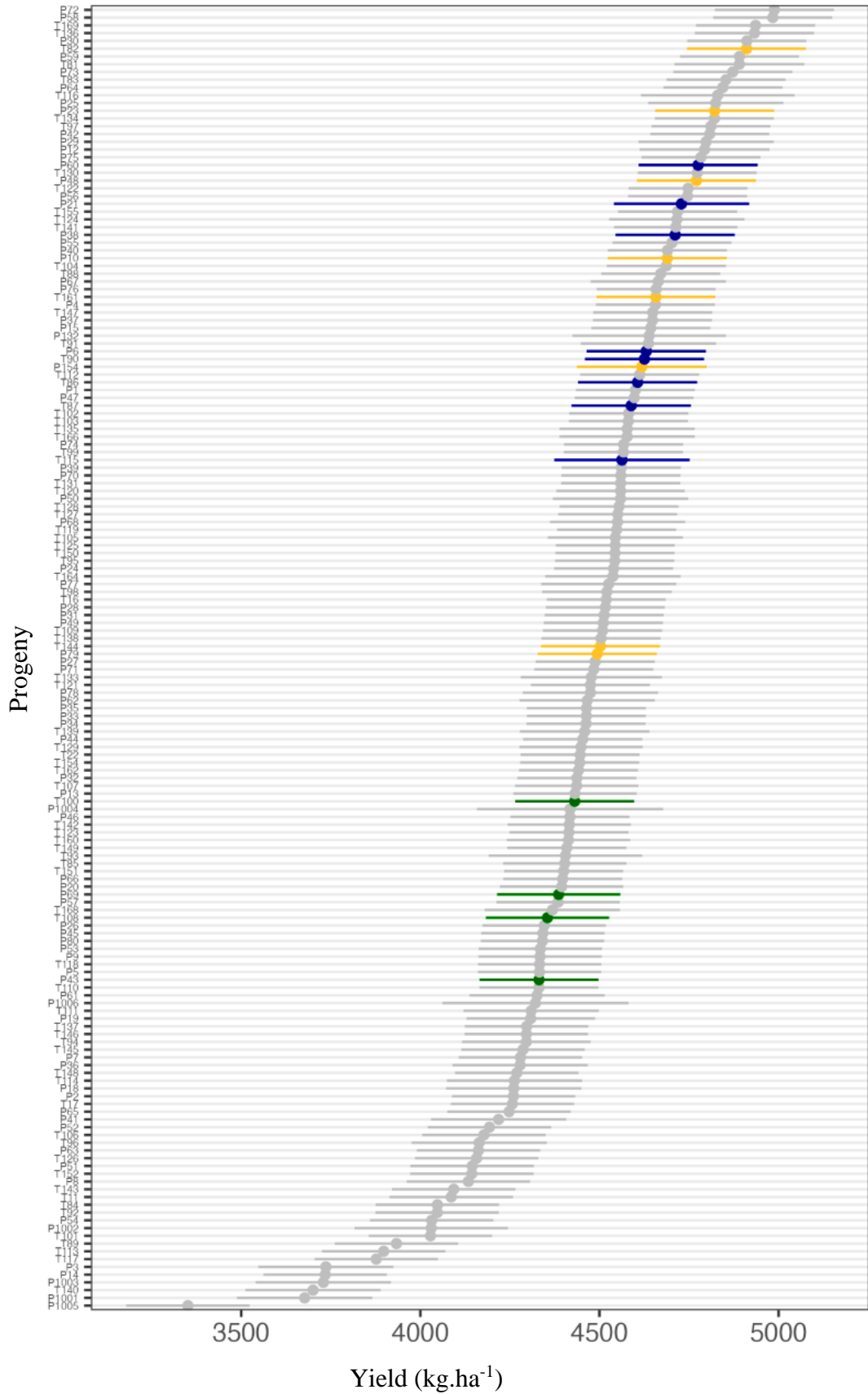
Source: From the author (2023).

Figure 7 showed the standard deviation and the predicted mean values of Flower Set (FS) and Yield for the evaluated early and late progenies, where the green dots represent the predicted mean values of the early and late progenies that show Yield values below the overall average of early progenies and Flower Set values below the overall average of late progenies. The yellow dots represent the predicted mean values of the early and late progenies that show Yield values higher the overall average of early progenies and Flower Set values below the overall average of late progenies. The blue dots represent the predicted mean values of the early and late progenies that show Yield values higher than the overall average of early progenies and Flower Set values higher than the overall average of late progenies. The gray dots represent the predicted mean values of the early and late progenies that show the intermediate Yield and Flower set values compared to other progenies (FIGURE 7).

Among all the evaluated progenies, seven stood out for presenting high floral set and high Yield (FIGURE 7). The early progenies that combine a high percentage of flower set and high yield are P60, P38, P21 and P6, while the late progenies are T90, T87, T86 and T115 (FIGURE 7; TABLE 1A).

The grain yield is determined not only by the number of pods produced, but also by factors such as the number of seeds per pod and the size of the seeds as noted by Van Schalk and Probst (1958). This could explain why, despite having a higher number of flowers, the late progenies did not have the highest yield average as shown in Figure 7 and Table 1A.

Figure 7 - Graphical representation of the predicted mean values for the Flower Set (FS) character combined with the Yield of the early and late F_{2:4} and F_{2:5} progenies in the four environments studied.



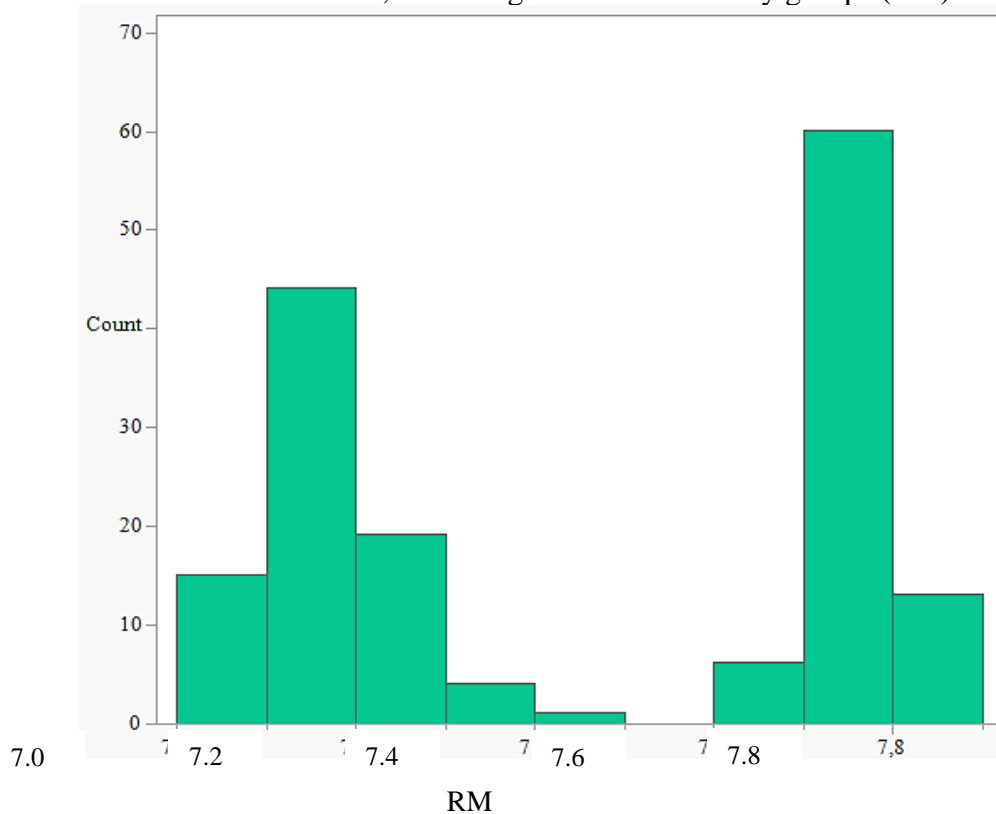
Source: From the author (2023).

The existing variability between the results of relative maturity (RM) among the progenies can also be observed in Figure 8. It is noted that there is variation among the progenies evaluated in terms of number of days for full maturity and, consequently, maturity group. This was expected since these were progenies previously selected based on the cycle and being classified as early/late.

The number of days to maturity is a trait that reflects precocity in soybean genotypes. These are classified into maturity groups, with an early cycle of up to 100 days, semi-early between 101 and 110 days, medium from 111 to 125 days, semi-late between 125 and 145 days, and late longer than 145 days (NEPOMUCENO *et al.*, 2008).

Alliprandini *et al.* (2009) pointed out that the vast majority of cultivars adapted to Brazilian conditions have a cycle of around 90 to 150 days, being classified between maturation groups 5 to 9. This classification is validated within the range of adaptation of the cultivar, ranging from according to latitude. For the regions of São Paulo, southern Minas Gerais and Mato Grosso do Sul (MRS 2), cultivars from groups 6 to 7 are recommended (ALLIPRANDINI *et al.*, 2009). Among the evaluated progenies, approximately 80% of the genotypes have a relative maturity group between 7 and 7.9, that is, suitable for planting in the region where the tests were installed, which is also evidenced by the results regarding the yield obtained (FIGURE 8; TABLE 1A).

Figure 8 - Frequency distribution of early and late F_{2:4} and F_{2:5} progenies, in the four environments studied, according to relative maturity groups (RM).



Source: From the author (2023).

Breeding programs have as their main objective the obtaining of superior individuals, which meet a certain demand, therefore estimating the gains with selection is essential, since these allow predicting the behavior of the progenies in the next generation.

Estimates of the expected gain with selection for the early and late progenies studied were obtained considering a 15% selection ratio. For the F_{2:5} generation, in addition to estimates of the expected gain with selection (EG), estimates of the realized gain (RG) with selection were obtained for the traits yield and floral setting (TABLE 6).

Regarding realized gains, both the estimated values for grain yield and floral setting were always lower than the estimates of expected gain with selection (TABLE 6), which can be explained, above all, by the effect of the genotype x environment interaction.

Soares *et al.* (2015), Silva *et al.* (2017), Zambiazzi *et al.* (2017), Gesteira *et al.* (2018) and Silva *et al.* (2022) reported a significant GxE interaction when evaluating soybean progenies in the southern region of the state of Minas Gerais, Brazil. To overcome GxE interaction challenges, several strategies might be applied. In the present study, selection was

performed based on the predicted values of the main effect of the genotypes obtained in the joint analysis of variance.

Estimates of the expected genetic gain and of the achieved genetic gain for the F_{2.4} and F_{2.5} generations were determined at 15% selection intensity (TABLE 6). A high variation was observed in the expected genetic gains, as a function of the intensity of selection. When a few individuals are selected for a given trait, higher selection gains are expected. However and Ramalho *et al.* (2012) and Cobb *et al.* (2019) concluded that a rigorous selection would strongly reduce genetic variability among progenies, which means that miss selection in early stages would greatly impact the efficiency of the breeding pipeline.

Although many factors affect genetic gain, in the present study, for grain yield and flower set, the GxE interaction component was greater than the genetic component (TABLE 4), directly affecting the genetic gain (SILVA *et al.*, 2022; BIANCHI *et al.*, 2020).

The achieved genetic gain ranged from 0.0002 to 1.1 for yield and FS, respectively, for both experiments. The lower estimates for yield and flower set can be explained by the complexity of the traits, which is harshly affected by location, crop year, planting date, rainfall, and other environmental factors (GESTEIRA *et al.*, 2018; RIBEIRO *et al.*, 2020; SOARES *et al.*, 2020; SILVA *et al.*, 2022). It is important to highlight that the soybean progenies faced drought conditions during the end of the reproductive stage in the Ijaci and Lavras cities of the 2020/2021 season, which affected the yield of the progenies as well as the floral setting (FIGURE 1b and 2b).

Table 6 - Estimates of expected gain with selection (EG) (%) using intensity of 15% and realized gain (RG) (%) in selection for grain yield (Yield) and Floral Setting (FS) traits. Data referring to early and late F_{2.4} and F_{2.5} progenies in the four environments studied.

Experiment	Yield		FS	
	EG	RG	EG	RG
Early	20.6	0.0002	4.9	1.1
Late	19.8	0.0002	3.8	1.1

Source: From the author (2023).

Understanding the relationship between traits is of great interest for plant breeding, especially for traits with low heritability and challenging measurement methods. Genetic correlations are hereditary and can be strategically used in breeding programs (CRUZ; CARNEIRO; REGAZZI, 2012).

The correlated response is the gain obtained in the secondary trait because of the selection for the primary trait. If two traits have a high and favorable correlation, that is, there is change in the phenotype according to the goal of the breeder it is possible to obtain satisfactory gains for the secondary trait through the selection for the primary trait. However, if the correlation is not favorable, the selection for a trait may lead to an unwanted change in the secondary trait (RIBEIRO *et al.*, 2020).

Positive correlations indicate the tendency of one characteristic to increase while another also increases, whereas negative correlations indicate the tendency of one characteristic to increase while the other decreases (CRUZ, CARNEIRO; REGAZZI, 2012). Therefore, knowing the meaning of the correlation between certain characters, it is possible to obtain indirect gains in a character by selecting another.

In the current study, the correlated response of -19.18 ($p > 0.01$) shows that when selecting progenies with high floral set, there is a reduction in trait Yield. The result shows that for each 1% increase in terms of floral setting, there is a reduction of 19.18 kg.ha⁻¹.

This result differs from previous findings by Ferrari *et al.* (2018) and Wiebold, Ashley and Boerma (1981), who reported a high correlation between Yield and flower set/pod in soybean. The results obtained in the present study are consistent with the conclusions of Xavier and Rainey (2020) who determined that pod number and node number had low heritability and a negative genetic correlation with yield. For effective indirect selection towards high yields, the traits selected must have a strong correlation with Yield, high heritability, and a low G x E interaction, as suggested by Kenga *et al.* (2006). The fact that the correlated response between the FS and Yield traits is negative, as well as the low heritability, makes indirect selection between these characters simultaneously unfeasible. Therefore, it is recommended to carry out selection based on joint data for both characters independently, rather than relying on the correlation between YIELD and FS.

4 CONCLUSION

In general, the FS trait showed little expressive genotypic variance values, and these were overcome by the residual variance in all studied environments, revealing that the genetic control of this trait is not predominantly genetic, making it difficult to obtain gains with selection, which in turn have a low proportion.

The selection of early and late progeny in trials resulted in a drastic reduction of the existing genetic variability. Additionally, the correlated response between the FS and Yield traits is negative, making the indirect selection of progenies with high yield and flower setting unfeasible.

The G x E interaction has a significant impact on the genetic and phenotypic parameters associated with yield and flower set in soybean, suggesting that future studies should consider a larger number of repetitions.

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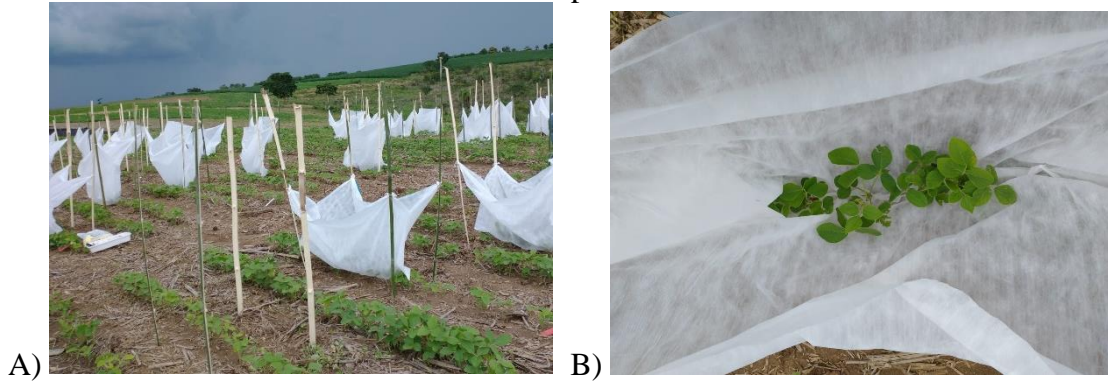
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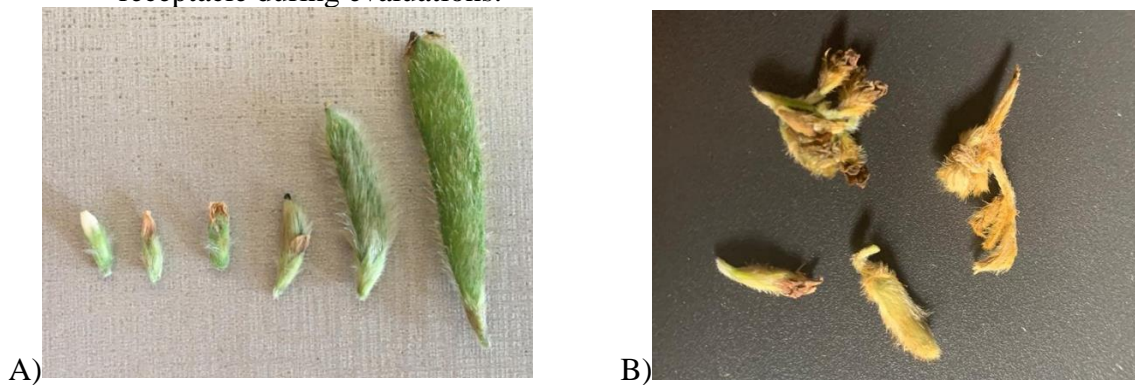
APPENDIX

Figure 1 - A) Floral receptacle used to collect aborted flowers. B) Aspect of the receptacle seen from above when it is installed in the plot.



Source: From the author (2023).

Figure 2 - A and B) Different soybean reproductive structures collected inside the floral receptacle during evaluations.



Source: From the author (2023).

Table 1A - Predicted values for Floral Set (FS) and Yield (Yield) (kg. ha⁻¹) referring to the evaluation of F_{2:4} and F_{2:5} lines, in the 2019/2020 and 2020/2021 seasons, respectively, at the Ijaci and Lavras- MG. Predicted values in relation to the average of the environments. (to be continued)

Progeny	FS	Yield
P72	0.83	4988
P58	0.81	4983
T169	0.82	4935
T136	0.81	4932
P30	0.83	4911
T82	0.78	4910
P59	0.83	4891
T81	0.81	4890
P73	0.84	4872
T83	0.83	4853
P64	0.82	4844
T116	0.83	4830
P25	0.82	4824
P23	0.75	4821
T134	0.81	4820
T97	0.83	4811
P42	0.81	4807
P29	0.81	4797
P12	0.82	4793
P75	0.79	4783
P60	0.84	4775
T130	0.79	4773
P48	0.78	4770
T122	0.82	4747
P56	0.81	4745
P21	0.85	4729
T155	0.81	4718
T124	0.84	4716
T141	0.82	4713
P38	0.84	4711
P55	0.82	4702
P10	0.76	4689
P40	0.81	4689
T104	0.81	4686
T88	0.81	4671
P67	0.82	4664

Table 1A - Predicted values for Floral Set (FS) and Yield (Yield) (kg. ha⁻¹) referring to the evaluation of F_{2:4} and F_{2:5} lines, in the 2019/2020 and 2020/2021 seasons, respectively, at the Ijaci and Lavras- MG. Predicted values in relation to the average of the environments. (to be continued)

Progeny	FS	Yield
P76	0.82	4658
T161	0.78	4657
P4	0.82	4656
P37	0.81	4648
T147	0.81	4648
P15	0.79	4643
P132	0.82	4638
T91	0.82	4636
P6	0.84	4630
T90	0.84	4625
P154	0.71	4618
T112	0.81	4612
T86	0.84	4606
P1	0.84	4600
P47	0.79	4597
T87	0.84	4588
T102	0.81	4581
T103	0.81	4580
T135	0.83	4577
T166	0.83	4577
P74	0.82	4567
T99	0.81	4566
T115	0.84	4562
P39	0.82	4560
P50	0.82	4559
P70	0.82	4559
T120	0.81	4559
T131	0.79	4559
T128	0.81	4554
T127	0.79	4551
P68	0.79	4550
T119	0.79	4548
T105	0.81	4544
T125	0.82	4544
T150	0.81	4543
T95	0.83	4542

Table 1A - Predicted values for Floral Set (FS) and Yield (Yield) (kg. ha⁻¹) referring to the evaluation of F_{2:4} and F_{2:5} lines, in the 2019/2020 and 2020/2021 seasons, respectively, at the Ijaci and Lavras- MG. Predicted values in relation to the average of the environments. (to be continued)

Progeny	FS	Yield
P24	0.79	4539
T164	0.82	4537
P77	0.82	4525
T98	0.79	4520
T16	0.81	4518
P28	0.81	4516
P31	0.81	4513
P49	0.79	4510
T109	0.81	4508
T138	0.81	4504
T144	0.77	4502
P79	0.78	4493
P27	0.81	4488
P71	0.82	4484
T133	0.81	4477
P78	0.82	4474
T121	0.86	4474
P62	0.78	4465
P33	0.81	4463
P35	0.82	4463
P34	0.82	4462
T139	0.82	4458
P44	0.82	4453
T129	0.81	4448
T22	0.82	4446
T154	0.68	4444
T162	0.85	4441
P32	0.79	4436
T107	0.84	4436
P13	0.81	4431
T100	0.77	4431
P46	0.82	4417
T142	0.82	4415
T123	0.81	4414
T160	0.82	4413
T149	0.82	4408

Table 1A - Predicted values for Floral Set (FS) and Yield (Yield) (kg. ha⁻¹) referring to the evaluation of F_{2:4} and F_{2:5} lines, in the 2019/2020 and 2020/2021 seasons, respectively, at the Ijaci and Lavras- MG. Predicted values in relation to the average of the environments. (to be continued)

Progeny	FS	Yield
T93	0.83	4405
T85	0.82	4403
T151	0.79	4400
P66	0.81	4397
P20	0.79	4394
P69	0.78	4386
P57	0.81	4384
T168	0.82	4368
T108	0.77	4355
P26	0.82	4345
P45	0.86	4342
P80	0.81	4340
P53	0.82	4335
P9	0.84	4334
P5	0.79	4332
T118	0.83	4332
P43	0.79	4331
T110	0.81	4331
P61	0.79	4326
T111	0.81	4309
P19	0.81	4308
T137	0.83	4296
T146	0.81	4295
T94	0.82	4295
T145	0.82	4286
P7	0.83	4279
P36	0.83	4278
T148	0.79	4269
T114	0.85	4262
P18	0.82	4260
P2	0.83	4260
T17	0.83	4257
P65	0.82	4247
P41	0.82	4218

Table 1A - Predicted values for Floral Set (FS) and Yield (Yield) (kg. ha⁻¹) referring to the evaluation of F_{2:4} and F_{2:5} lines, in the 2019/2020 and 2020/2021 seasons, respectively, at the Ijaci and Lavras- MG. Predicted values in relation to the average of the environments. (conclusion)

Progeny	FS	Yield
P52	0.82	4193
T106	0.83	4177
T96	0.81	4164
P63	0.82	4162
T126	0.83	4156
P51	0.81	4144
T152	0.82	4143
P8	0.81	4134
T143	0.83	4093
T11	0.83	4086
T84	0.84	4047
T92	0.82	4047
P54	0.83	4031
T101	0.82	4028
T89	0.83	3933
T113	0.84	3897
T117	0.83	3876
P3	0.84	3736
P14	0.86	3734
T140	0.82	3700

Source: From the author (2023).