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Influence of weed free periods on the growth, yield and quality of soybean (*Glycine max* L.)

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during December 2018 to May 2019 to study the influence of weed free periods on the growth, yield and quality of soybean (*Glycine max* L.). The experiment was laid out in a randomized complete block design with three replications. The experiment comprised three varieties *viz.* Binasoybean-1, Binasoybean-3 and BARI Soybean-6, and five weed free periods *viz.* weedy check, weed free up to 20 days after sowing (DAS), weed free up to 40 DAS, weed free up to 60 DAS and weed free throughout the growth period. The BARI Soybean-6 produced the tallest plant (44.75 cm), the highest number of nodules plant^{-1} (30.17) and dry matter plant^{-1} (7.37 g) at 80 DAS for the weed free growth period. Similarly, at harvest, BARI Soybean-6 gave the highest plant height (45.99 cm), number of pods plant^{-1} (24.27), 1000-seed weight (115.20 g), seed yield (1.58 t ha^{-1}), stover yield (1.92 t ha^{-1}), protein content (43.96%) and oil content (18.70%) while Binasoybean-1 showed the lowest results of all parameters. Weed free throughout the growth period produced the highest plant height (47.92 cm), number of branches plant^{-1} (6.26), number of pods plant^{-1} (33.04), 1000-seed weight (123.10 g), seed yield (1.82 t ha^{-1}), stover yield (2.15 t ha^{-1}), protein content (44.80%) and oil content (19.47%) whereas the corresponding lowest values were recorded in weedy check. Seed yield increased by 91.58% in weed free throughout the growth period compared to weedy check. In case of interaction, the highest seed yield (1.97 t ha^{-1}), stover yield (2.28 t ha^{-1}) and protein content (45.50%) were observed in BARI Soybean-6 along with weed free throughout the growth period which was at par with BARI Soybean-6 with weed free up to 60 DAS while the lowest values of all parameters were found in Binasoybean-1 with weedy check treatment. In conclusion, BARI Soybean-6 along with weed free up to 60 DAS is the promising combination for soybean cultivation.

Keywords: Soybean, variety, weed, yield, protein and oil content

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1 Introduction

Soybean (*Glycine max* L.) is one of the important grain legumes of the world and a new prospective crop for Bangladesh (Rahman et al., 2011). It supplies high quality protein (over 40%) for human and livestock consumption as well as oil (about 20%) on a dry matter basis which is 85% unsaturated and cholesterol-free (Dugje et al., 2009). In Bangladesh, soybean covers more than 11% area among the oil seed crops which produced approximately 10 thousand tons (BBS, 2019). Bangladesh has to spend a huge amount of foreign currency on imports of edible oils and oilseeds to meet the increasing demand of its population. The values of imported edible oils and oilseeds were $1574 million and $354 million in 2014-2015, respectively (BB, 2016). In Bangladesh, soybean is mostly used for making nutritious food dishes and confectionary items such as soyadal, soyakhechuri, soyabread, soyamilk and so on (Rahman, 2003). Now-a-days soybean is widely used as fish meal (Phumee et al., 2011; Kader et al., 2012) and poultry feed (Serrano et al., 2013). In addition to its use as a source of protein and fodder, it can improve soil fertility by contributing to soil nitrogen through nitrogen fixation (Kureh et al., 2005). Soybean can be cultivated throughout the year in Bangladesh. Although the climatic and the edaphic conditions of Bangladesh are favorable for soybean production, the yield of this crop is very low compared to other soybean growing countries. Among the various factors responsible for low yield of soybean in Bangladesh, variety selection and weed management are very important. Variety plays an important role in producing high yield of soybean. Unavailability of quality seeds of soybean for sowing is a major problem in soybean cultivation. The lower yield at farmers' level is attributed to the poor agronomic management practices and also due to use of low quality seed (Rahman and Islam, 2006).

Bangladesh Agricultural Research Institute and Bangladesh Institute of Nuclear Agriculture have released a good number of improved varieties of oilseeds. The rate of adoption of these improved varieties at farm level is encouraging (Miah et al., 2015, 2016). The selection of improved and high yielding soybean genotypes with wide range of adaptation to soil and environment conditions is essential to increase the yield. Weeds compete with crop plants and utilize considerable amount of moisture, nutrients and space in photosphere and atmosphere, thus deprive opportunities for the crop to express its potential yield. The reduction in soybean yield due to weed infestation ranges from 20-77% (Kurchania et al., 2001). Weed infestation removed 21.4 kg N and 3.4 kg P ha^{-1} in soybean (Pandya et al., 2005). Application of two hand hoeing is more effective in suppressing weeds and increasing soybean seed yield (Ahmed et al., 2001). So, weed management is necessary to boost up the yield of soybean. The present study was, therefore, undertaken to determine the effects of variety and weed free periods on the growth, yield and quality of soybean.

2 Materials and Methods

2.1 Experimental site

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during December 2018 to May 2019. The experimental site was located at 24°43′8.3″N, 90°25′41.2″E at an elevation of 18 m from the sea level. The site belongs to the non-calcareous dark grey floodplain soil under the Old Brahmaputra Floodplain (Agro-ecological Zone-9) (UNDP and FAO, 1988).

2.2 Experimental treatments and design

The experiment comprised three varieties *viz.* Binasoybean-1, Binasoybean-3 and BARI Soybean-6 and five weed free periods *viz.* weedy check (no weed free period), weed free up to 20 days after sowing (DAS), weed free up to 40 DAS, weed free up to 60 DAS and weed free throughout the growth period. The experiment was laid out in randomized complete block design with three replications. The size of each unit plot was 2.5 m × 2.0 m.

2.3 Collection of seed

The seeds of Binasoybean-1 and Binasoybean-3 were collected from BINA, Mymensingh and seeds of BARI Soybean-6 were collected from BARI, Joydebpur, Gazipur.

2.4 Crop husbandry

The experimental land was first opened with a tractor on 10 December 2018. Then the land was prepared by ploughing and cross-ploughing with a country plough and subsequently leveled by laddering. All weeds and stubbles were removed from the land. The field layout was accomplished according to the experimental design adopted on 26 December 2018. The land was fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum at the rate of 60, 170, 120 and 100 kg ha^{-1}, respectively. The entire amount of urea, TSP, MoP and gypsum were applied at final land preparation. The seeds of soybean were sown on 26 December 2018 in furrow maintaining 30 cm × 10 cm spacing with two seeds per hole. Seeds germination was started within eight days after sowing (DAS). Thinning was done at 28 DAS to maintain optimum plant population in each plot and weeding was done as per experimental treatments. No irrigation was required for the crop.

During experimental period, there was heavy rainfall for several times and water was drained out properly after each heavy rainfall. No remarkable infestation of insect and disease organisms was noticed in the field due to heavy rainfall as well as other climatic condition. Therefore, no plant protection measure was undertaken.

2.5 Data collection for weeds

Weed density was calculated species-wise at 60 DAS and at harvest using a quadrate of 0.25 m^2 placed randomly at two places of each plot. The weeds within the quadrate were counted and converted to number m^{-2}. After determining the weed density, the weeds inside each quadrate were uprooted and cleaned. The collected weeds were then dried in an electric oven for 72 hours at a temperature of 70 °C. After drying, the dry weight of each plot was recorded by an electrical balance and converted to g m^{-2}.

2.6 Data collection at vegetative stage

At 60 and 80 DAS, five plants were randomly selected and marked with bamboo sticks in each plot excluding border rows to record the data on plant height, number of nodules $plant^{-1}$ and leaf chlorophyll content by SPAD meter. Chlorophyll content was measured from five fully expanded young leaves of each sample plant. To determine dry matter production, two plants were randomly uprooted from each plot excluding border rows at 60 DAS and 80 DAS. Then the plants were uprooted and put into envelop and dried in an electric oven for 72 hours maintaining a constant temperature of 70 °C. After drying, weight of each sample was recorded by an electrical balance and converted to g m^{-2}.

2.7 Data collection at harvest

At the time when 90% of the pods became brown in colour, the crop was assessed to attain maturity. Five plants were selected randomly from each unit plot and uprooted to record data on crop characters, yield components and yield. After sampling, the whole plot was harvested at full maturity. BARI Soybean-6, Binasoybean-1 and Binasoybean-3 were harvested on 25 April, 29 April and 2 May 2019, respectively. The harvested crops of each plot was separately bundled, properly tagged and then brought to the threshing floor of Agronomy Field Laboratory and sun dried for three days. Seeds were separated from the plants by beating the bundles with bamboo sticks. The seeds were then cleaned and sun dried for four consecutive days for achieving safe moisture content. Seed and stover yields obtained from five sample plants were added with the respective whole plot harvest to get the actual seed and stover yields. Finally seed and stover yields were recorded and converted to t ha^{-1}.

2.8 Data collection on quality characters

Protein content (%) in seeds was estimated by Micro-Kjeldahl method (AOAC, 1984) at Professor Muhammad Hossain Central Laboratory, Bangladesh Agricultural University, Mymensingh. Oil content (%) was estimated with the help of Soxhlet apparatus at the laboratory of Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh.

2.9 Statistical analysis

Data were compiled and tabulated in proper form for statistical analysis. All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

3 Results and Discussion

3.1 Crop growth characters

Crop growth characters *viz.* plant height, number of nodules $plant^{-1}$, leaf chlorophyll content (SPAD value) and dry matter production $plant^{-1}$ of soybean were significantly influenced by variety where BARI Soybean-6 produced higher results than Binasoybean-1 and Binasoybean-3 at 80 DAS (Table 1). At 80 DAS, the highest plant height (38.85 cm) was recorded in BARI Soybean-6 which was statistically identical to Binasoybean-3 and the highest number of nodules $plant^{-1}$ (16.23) was obtained in BARI Soybean-6 while the lowest plant height (34.22 cm) and number of nodules $plant^{-1}$ (10.30) were recorded from Binasoybean-1. On the other hand, the highest chlorophyll content (33.21) and dry matter production $plant^{-1}$ (4.66 g) were found in BARI Soybean-6 while the corresponding lowest values were found in Binasoybean-3 (Table 1). Umeh et al. (2011) reported that plant height and total dry matter varied according to variety.

The different weed free periods had significant effect on crop growth characters of soybean where weed free throughout the growth period produced higher results than other weed free periods at 80 DAS (Table 1). At 80 DAS, the highest plant height (41.58 cm), number of nodules $plant^{-1}$ (22.39), leaf SPAD value (36.79) and dry matter production $plant^{-1}$ (6.69 g) were obtained in weed free throughout the growth period whereas the lowest values of all parameters were obtained in weedy check treatment (Table 1). These results indicate that crop growth characters increased with the increase of weed free periods and

Table 1. Effect of variety and weed free periods on number of nodules plant^{-1}, leaf chlorophyll content and dry matter production plant^{-1} at different days after sowing of soybean

Treatments	Plant height (cm)		No. of nodules plant^{-1}		SPAD value		DM plant^{-1} (g)	
	60 DAS	80 DAS	60 DAS	80 DAS	60 DAS	80 DAS	60 DAS	80 DAS
Variety								
Binasoybean-1	28.28b	34.22b	10.03c	10.30c	26.33	31.19b	1.30b	4.24b
Binasoybean-3	29.53a	38.13a	12.30b	11.74b	26.58	30.46b	1.35b	4.15b
BARI Soybean-6	30.22a	38.85a	14.63a	16.23a	26.82	33.21a	1.83a	4.66a
Weed free periods								
W0	24.44e	32.93d	5.89d	3.28e	19.15e	24.68d	0.75e	1.14d
W1	26.67d	34.53d	9.66c	7.55d	20.05d	30.61c	0.89d	1.87c
W2	29.69c	36.94c	11.22b	12.11c	28.53c	32.92b	1.51c	5.96b
W3	31.94b	39.33b	17.32a	18.44b	30.96b	33.10b	1.78b	6.09b
W4	33.97a	41.58a	17.50a	22.39a	34.21a	36.79a	2.57a	6.69a
Sig. level	**	**	**	**	**	**	**	**
CV (%)	3.66	4.77	8.76	7.16	3.39	3.96	6.14	3.32

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability; W0 = Weedy check (no weed free period), W1 = Weed free up to 20 days after sowing (DAS), W2 = Weed free up to 40 DAS, W3 = Weed free up to 60 DAS, W4 = Weed free throughout the growth period

Table 2. Interaction effect of variety and weed free periods on number of nodules plant^{-1}, leaf chlorophyll content and dry matter production plant^{-1} at different days after sowing of soybean

Interaction	Plant height (cm)		No. of nodules plant^{-1}		SPAD value		DM plant^{-1} (g)	
	60 DAS	80 DAS	60 DAS	80 DAS	60 DAS	80 DAS	60 DAS	80 DAS
V1 × W0	24.00i	31.75i	5.00j	3.00k	19.67gh	21.95j	0.67j	1.05h
V1 × W1	25.58hi	32.25hi	8.33hi	5.83j	19.24h	30.29fg	0.67j	1.66f
V1 × W2	29.58ef	34.08fghi	11.00fg	9.50h	29.70de	32.55def	1.63e	6.16c
V1 × W3	30.50de	34.25fghi	12.83ef	15.33ef	30.72cd	32.90cde	1.60e	6.06c
V1 × W4	31.75cd	38.75cde	13.00e	17.83cd	32.33c	38.24a	1.93d	6.28bc
V2 × W0	25.08hi	32.88ghi	6.00j	3.17k	18.39h	24.69i	0.76j	1.06h
V2 × W1	27.75fg	36.00efg	9.67gh	7.67i	19.96gh	28.50gh	0.94hi	1.58f
V2 × W2	30.17de	39.83cd	10.33g	12.00g	27.15f	31.64ef	1.12g	5.66d
V2 × W3	31.17de	40.67bc	18.67c	16.67de	31.17cd	31.51ef	1.39f	6.06c
V2 × W4	33.50bc	41.25bc	16.83d	19.17c	36.25a	35.94b	2.56b	6.43b
V3 × W0	24.25i	34.17fghi	6.67ij	3.67k	19.38gh	27.39h	0.82ij	1.31g
V3 × W1	26.67gh	35.33fgh	11.00fg	9.17hi	20.95g	33.03cde	1.04gh	2.39e
V3 × W2	29.33ef	36.92def	12.33ef	14.83f	28.73e	34.58bcd	1.75e	6.06c
V3 × W3	34.17b	43.08ab	20.48b	23.33b	30.99cd	34.88bc	2.34c	6.17c
V3 × W4	36.67a	44.75a	22.67a	30.17a	34.06b	36.18ab	3.21a	7.37a
Sig. level	**	**	**	**	**	**	**	**
CV (%)	3.66	4.77	8.76	7.16	3.39	3.96	6.14	3.32

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);
** = Significant at 1% level of probability; V1 = Binasoybean-1, V2 = Binasoybean-3, V3 = BARI Soybean-6; W0 = Weedy check (no weed free period), W1 = Weed free up to 20 days after sowing (DAS), W2 = Weed free up to 40 DAS, W3 = Weed free up to 60 DAS, W4 = Weed free throughout the growth period

Table 3. Effect of variety and weed free periods on yield components, yield and quality of soybean

Treatments	PH (cm)	Branch plant^{-1}	Pods plant^{-1}	Seeds pod^{-1}	WTS (g)	SY (t ha^{-1})	StY (t ha^{-1})	PrCont. (%)	OilCont. (%)
Variety									
Binasoybean-1	39.26b	4.40c	19.12c	2.73	110.80b	1.26c	1.61c	40.46c	18.20b
Binasoybean-3	43.73a	5.64a	21.37b	2.78	111.60b	1.51b	1.85b	42.36b	18.62a
BARI Soybean-6	45.99a	5.13b	24.27a	2.77	115.20a	1.58a	1.92a	43.96a	18.70a
Weed free periods									
W0	37.89c	3.60d	11.42e	2.62c	94.27d	0.95d	1.44e	39.90d	17.33d
W1	41.48b	4.40c	12.69d	2.68c	104.50c	1.23c	1.62d	41.07c	17.90c
W2	43.07b	5.22b	21.84c	2.73bc	118.50b	1.49b	1.74c	42.37b	18.80b
W3	44.60b	5.80a	28.93b	2.84ab	122.20a	1.76a	2.02b	43.17b	19.03ab
W4	47.92a	6.26a	33.04a	2.93a	123.10a	1.82a	2.15a	44.80a	19.47a
Sig. level	**	**	**	**	**	**	**	**	**
CV (%)	7.33	9.67	3.64	5.01	3.18	4.74	3.31	2.03	2.73

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability; W0 = Weedy check (no weed free period), W1 = Weed free up to 20 days after sowing (DAS), W2 = Weed free up to 40 DAS, W3 = Weed free up to 60 DAS, W4 = Weed free throughout the growth period; PH = plant height, WTS = 1000-seed weight, SY = seed yield, StY = stover yield, PrCont. = protein content, OilCont. = oil content

Table 4. Interaction effect of variety and weed free periods on yield components, yield and quality of soybean

Treatments	PH (cm)	Branch plant^{-1}	Pods plant^{-1}	Seeds pod^{-1}	WTS (g)	SY (t ha^{-1})	StY (t ha^{-1})	PrCont. (%)	OilCont. (%)
V1 × W0	34.03	3.46	10.53k	2.6	88.55f	0.87f	1.37g	38.50g	16.8
V1 × W1	37.45	3.66	11.67ijk	2.66	94.16ef	1.06e	1.43fg	39.90efg	17.9
V1 × W2	39.57	4.46	18.47g	2.73	123.70ab	1.25d	1.53f	39.20fg	18.6
V1 × W3	40.16	4.86	24.27e	2.8	123.60ab	1.52c	1.80d	40.60ef	18.5
V1 × W4	45.08	5.53	30.67c	2.86	123.80a	1.60bc	1.95c	44.10abc	19.2
V2 × W0	39.52	3.73	10.87jk	2.66	99.53de	0.98ef	1.45fg	39.90efg	17.5
V2 × W1	43.09	5.06	12.20ij	2.73	103.90d	1.29d	1.68e	40.60ef	17.9
V2 × W2	43.89	5.86	20.87f	2.73	114.80c	1.53c	1.78de	43.10c	18.9
V2 × W3	44.7	6.6	29.73c	2.86	119.70abc	1.86a	2.09b	43.40bc	19.2
V2 × W4	47.43	6.93	33.20b	2.93	120.20abc	1.90a	2.24a	44.80ab	19.6
V3 × W0	40.13	3.6	12.87i	2.6	94.72ef	1.01e	1.49f	41.30de	17.7
V3 × W1	43.89	4.46	14.20h	2.66	115.60c	1.34d	1.74de	42.70cd	17.9
V3 × W2	45.75	5.33	26.20d	2.73	117.00bc	1.69b	1.92c	44.80ab	18.9
V3 × W3	48.95	5.93	32.80b	2.86	123.40ab	1.92a	2.17ab	45.50a	19.4
V3 × W4	51.24	6.33	35.27a	3	125.40a	1.97a	2.28a	45.50a	19.6
Sig. level	NS	NS	**	NS	**	*	**	**	NS
CV (%)	7.33	9.67	3.64	5.01	3.18	4.74	3.31	2.03	2.73

Figures in a column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); * and ** denote Significant at 5% and 1% level of probability, respectively; V1 = Binasoybean-1, V2 = Binasoybean-3, V3 = BARI Soybean-6, W0 = Weedy check (no weed free period), W1 = Weed free up to 20 days after sowing (DAS), W2 = Weed free up to 40 DAS, W3 = Weed free up to 60 DAS, W4 = Weed free throughout the growth period; PH = plant height, WTS = 1000-seed weight, SY = seed yield, StY = stover yield, PrCont. = protein content, OilCont. = oil content

no weeding condition adversely affected on plant growth and development. The interaction of variety and weed free periods exerted significant affect on crop growth characters of soybean at 80 DAS (Table 2). At 80 DAS, the tallest plant (44.75 cm) was recorded in BARI Soybean-6 with weed free throughout the growth period that was at par with BARI Soybean-6 along with weed free up to 60 DAS. The highest number of nodules plant^{-1} (30.17) and dry matter production plant^{-1} (7.37 g) were recorded in the interaction of BARI Soybean-6 with weed free throughout the growth period while the highest leaf chlorophyll content (38.24) was found in Binasoybean-1 with weed free throughout the growth period which was at par with BARI Soybean-6 with weed free throughout the growth period treatment. On the other hand, the corresponding lowest values were obtained in Binasoybean-1 with weedy check treatment (Table 2).

3.2 Yield components and yield

Varieties of soybean exerted significant effect on yield components and yield of soybean except number of seeds pod^{-1} (Table 3). The tallest plant (45.99 cm) was observed in BARI Soybean-6 which was at par with Binasoybean-3 and the highest number of branches plant^{-1} (5.64) was observed in Binasoybean-3. The highest number of pods plant^{-1} (24.27), 1000-seed weight (115.20 g), seed yield (1.58 t ha^{-1}), stover yield (1.92 t ha^{-1}) and harvest index (44.78%) were obtained in BARI Soybean-6 (Table 3). The variation in number of branches plant^{-1}, number of pods plant^{-1}, 1000-seed weight and seed yield among varieties might be due to genetic constituents of the crop. The higher seed yield in BARI Soybean-6 might be due to the contribution of more number of pods plant^{-1}, more number of seeds pod^{-1} and 1000-seed weight. Weed free periods also significantly influenced yield attributes and quality parameters of soybean (Table 3). The tallest plant (47.92 cm) was found in weed free throughout the growth period while the shortest one (37.89 cm) was found in weedy check treatment. The highest number of branches plant^{-1} (6.26), number of seeds pod^{-1} (2.93), 1000-seed weight (123.10 g) and seed yield (1.82 t ha^{-1}) were found in weed free throughout the growth period which were statistically identical with weed free up to 60 DAS. The highest number of pods plant^{-1} (33.04) and stover yield (2.15 t ha^{-1}) were obtained in weed free throughout the growth period treatment. The lowest values of all parameters were recorded in control treatment. Soybean yield increased by 91.58% in weed free throughout the growth period compared to weedy check and weed free up to 60 DAS, weed free up to 40 DAS and weed free up to 20 DAS increased seed yield by 85.26%, 56.84% and 29.47%, respectively compared to weed control treatment (Table 3). Weed severely competed with crop plants for nutrient, moisture and sunlight, subsequently reduced yield components, yield and quality of soybean.

The interaction of variety and weed free periods had significant effect on yield components and yield of soybean except plant height, number of branches plant^{-1}, number of seeds pod^{-1}, and harvest index (Table 4). The highest number of pods plant^{-1} (35.27) was obtained in BARI Soybean-6 with weed free throughout the growth period. The highest weight of 1000-seed (125.40 g) was observed in BARI Soybean-6 with weed free throughout the growth period which shown statistically identical to the interactions of Binasoybean-1 with weed free throughout the growth period and BARI Soybean-6 with weed free up to 60 DAS. The highest seed (1.97 t ha^{-1}) and stover (2.28 t ha^{-1}) yields were obtained in BARI Soybean-6 with weed free throughout the growth period which was at par with BARI Soybean-6 along with weed free up to 60 DAS. On the other hand, the lowest number of pods plant^{-1} (10.53), 1000-seed weight (88.55 g), seed yield (0.87 t ha^{-1}) and stover yield (1.37 t ha^{-1}) were recorded in Binasoybean-1 along with weedy check treatment (Table 4).

3.3 Quality parameters

3.3.1 Oil content

Oil content was significantly influenced by variety (Table 3). The highest amount of oil (18.70%) was produced in BARI Soybean-6 which was at par with Binasoybean-3 while the lowest one (18.20) was recorded in Binasoybean-1 (Table 3). Weed free periods significantly influenced the oil content of soybean seeds (Table 3). The highest oil content (19.47%) was found in weed free throughout the growth period which was at par with weed free up to 60 DAS while the weedy check treatment produced the lowest value (17.33%) of oil content (Table 3). Numerically, BARI Soybean-6 along with weed free period throughout the growth period recorded the highest amount of oil (19.60%) which was similar to Binasoybean-3 along with weed free period throughout the growth period while the lowest value was recorded in Binasoybean-1 along with weedy check (Table 4).

3.3.2 Protein content

Protein content in soybean seed was significantly influenced by variety (Table 3). The highest protein content (43.96%) was obtained in BARI Soybean-6 followed by Binasoybean-3 (42.36%) and Binasoybean-1 (40.46%) (Fig. 1 and Table 3). Weed free period significantly influenced the protein content of soybean seeds (Table 3). The highest protein (44.80%) was found in weed free period throughout the growth period followed by weed free up to 60 DAS while the weedy check treatments produced the lowest values of protein percent (Table 3). BARI Soybean-6

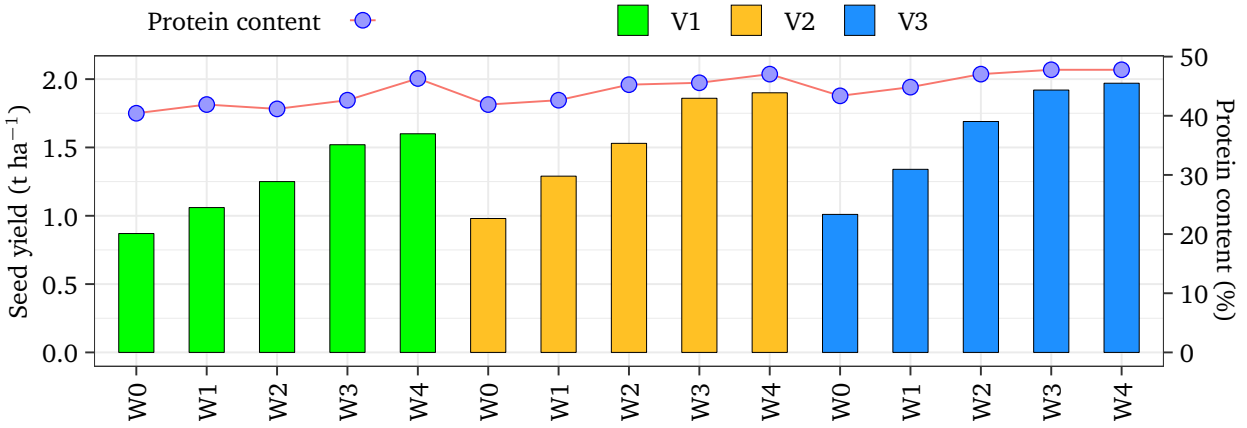

Figure 1. Interaction effect of variety and weed free periods on seed yield and protein content of soybean. V1 = Binasoybean-1, V2 = Binasoybean-3, V3 = BARI Soybean-6

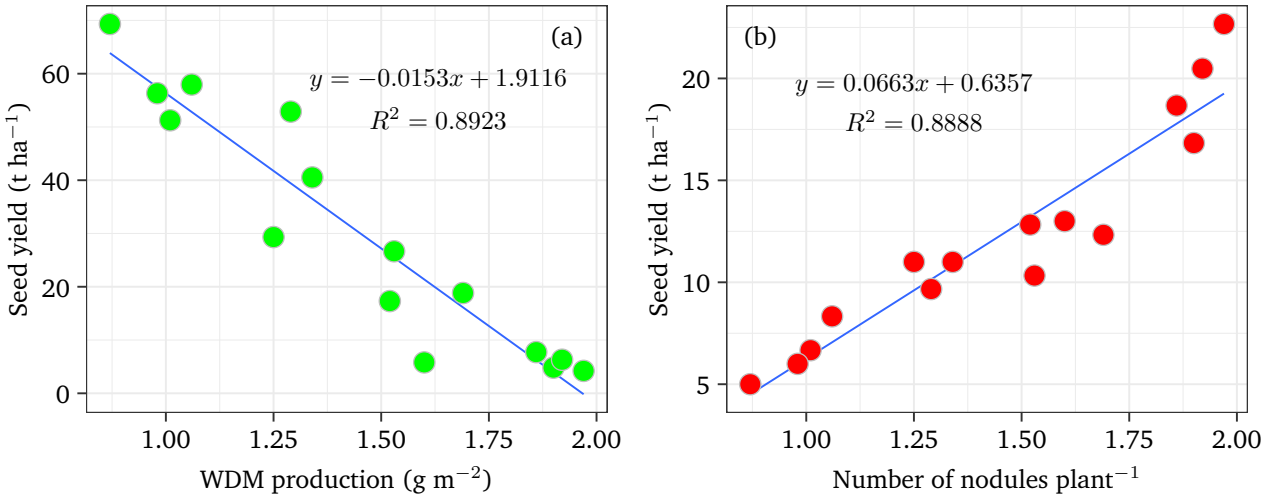

Figure 2. Relationship between (a) weed dry matter (WDM) production at 60 DAS, and (b) number of nodules plant^{-1} at 60 DAS with seed yield of soybean

along with weed free throughout the growth period contain highest amount of protein (45.50%) which was significantly similar to BARI Soybean-6 along with weed free up to 60 DAS which was at par with BARI Soybean-6 along with weed free up to 40 DAS while the lowest value (38.50%) was recorded in Binasoybean-1 along with weedy check (Table 4).

3.4 WDM *vs* seed yield

A negative relationship between weed dry matter production m^{-2} at 60 DAS and seed yield of soybean was observed, which indicated that the higher the weed dry matter production the lower the seed yield. The response of weed dry matter production to the seed yield of soybean followed a linear negative relationship which could be adequately described by regression equation. The regression equation indicates that an increase in weed dry matter weight would lead to a decrease in the seed yield of soybean (Fig. 2a). The functional relationship was highly significant at p≤0.01. The functional relationship can be determined by regression equation, $y = -0.0153x + 1.9116$ ($R^2 = 0.8923$). The functional relationship revealed that 89% of the variation in seed yield could be explained from the variation in total weed dry matter production at 60 DAS. This findings is in agreement with that of Sinha et al. (2018) who reported that 89% of Boro rice (cv. BRRI dhan50) yield could be explained by the functional relationship of weed dry matter production at 65 DAT while Islam et al. (2015) reported that 80% of the variation in grain yield could be explained from the variation in weed dry matter production at 60 DAT in BRRI dhan49.

3.5 Nodule number *vs* seed yield

A positive relationship between number of nodules plant^{-1} at 60 DAS and seed yield of soybean was observed, which indicated that higher the number of nodules the higher the seed yield. The response of number of nodules to the seed yield of soybean followed a linear positive relationship which could be adequately described by regression equation. The regression equation indicates that an increase in number of nodules would lead to an increase in the seed yield of soybean (Fig. 2b). The functional relationship was significant at p$\leq$0.01. The functional relationship can be determined by regression equation, $y = 0.0663x + 0.6357$ ($R^2 = 0.89$). The functional relationship revealed that 88% of the variation in seed yield could be explained from the variation in number of nodules plant^{-1} at 60 DAS.

4 Conclusions

This study demonstrated that among the tested varieties BARI Soybean-6 was superior to other varieties in respect of growth, yield and quality of soybean. Among the different weed free periods, weed free throughout the growth period produced the highest seed yield. The highest seed yield was recorded from the interaction of BARI Soybean-6 with weed free throughout the growth period which was at par with BARI Soybean-6 along with weed free up to 60 DAS. It can be concluded that BARI Soybean-6 along with weed free up to 60 DAS emerged as the promising one in respect of seed yield and quality of soybean compared to other treatment combinations.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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