J. Agric. Food. Tech., **2(4)73-78, 2012**

ISSN 2090 – 424X
Journal of Agriculture and Food Technology
www.textroad.com

The Effect of Planting Date and Harvesting Time on the Yield and Seed Quality of Rainy Season Soybean (*Glycine max* (L.) Merr.)

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ABSTRACT

Field and laboratory experiments were done to study the effect of planting date and harvesting time on the yield and seed quality of soybean (*Glycine max* (L.) Merr) planted in the rainy season. The field experiment was done in Malang, Indonesia (112^{o}.37'41" East, 7o.58'40" South) with the treatment of 4 levels planting time: (1) at the commencement of rainy season; (2) 2 weeks, (3) 4 weeks and (3) 6 weeks after the commencement of rainy season), and 3 levels of harvesting time (85 % maturity; 100 % maturity; and post maturity). A laboratory experiment was carried to study the effect of the time of seed storage on the seed germination and seedling vigor. The experimental results discussed above show that the growth of the rainy soybean was influenced by planting date. The yield as well as seed quality of rainy soybean were significantly influenced by planting date and harvesting time. To obtain a high yield and good quality seed, the plant should be planted not later than 2 weeks after the commencement of the rainy season. The seed of these treatments had higher carbohydrate content, and a more stable seed germination rate. Delayed planting date was not only decrease the yield, but also decrease seed quality which result in rapid decrease of germination rate

Keywords: Soybean yield, seed germination, seedling vigor, Indonesia

INTRODUCTION

Soybean ((*Glycine max* (L.) Merr.) is known as subtropical crops, but grow well and has for long time been grown in Indonesia. Soybean is the most important nabati protein which is consumed in the form of "tempe" , tofu, and to some extend as soy-sauce. However, national soybean production was not enough to meet the requirement, and hence Indonesian government should import from other countries. Looking the important role of soybean in Indonesian economic, since 1983 Indonesian government **has** declared to fulfill soybean needs from the national production. After revised several times, the government declared that Indonesia will self sufficient for their soybean requirement, with the target to produce 3.0 millions ton/year, in the year of 2014 [1]. However, since 1992 there was a continue decrease in soybean production [2], so that it is doubtful that the self sufficient can be achieved.

In Indonesia, soybean is planted in lowland area after rice when there was not enough water or in upland area at the beginning of the rain season [3]. With the improvement of irrigation networks, and the discovery of short maturity rice, the lowland planted with soybean continually decreased. In the year of 1992, for example there was 1.7 millions ha of soybean harvested area decreased to only 0.53 millions ha in 2003. The yield of soybean on upland area, on the other hand, is very low, much lower than that obtained on lowland area. A lot of factors responsible for the low yield of upland soybean, one of them is due to the incompatible of planting time. It is difficult to decide when should plant soybean planted in rainy season. To early planting soybean, it is afraid that the rain is not continuing so that the plant will suffer water stress. To postpone planting date, on the other side, will face a risk of excessive rain which has detrimental effect on soybean growth.

It has been understood that planting date is one of the important factor that control soybean growth and yield [4][5]. Planting date will determine water availability which is very important for plant growth [6], temperature, humidity, and to some extend day length. In tropical region, such as Indonesia, day length is not vary much. However, planting date definitely will influence water availability, temperature and relative humidity. These variables are the important factors which control soybean growth, flower initiation, seed development, and hence crop yield.

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The other difficulty for developing soybean in Indonesia is to obtain a good seed quality. It has been widely known that soybean seed has a short dormancy period. A good seed quality is expected to have a longer dormancy period, and hence it will have high germination rate with a good seedling vigor, and hence will produce a better soybean growth and yield. Some workers [7][8] suggested that planting date will influence seed development and seed quality, because it determine some factors which control protein formation. Our literature studies shows that, in Indonesia, most study of planting date for soybean was done for lowland soybean [3][9].

The experiments reported here were aimed to study the effect planting date on the growth, yield and seed quality of soybean planted on the beginning of rainy season. The seed quality was also studied from point of view seed germination and vigor growth of the seedling.

MATERIALS AND METHODS

The field experiment was carried out in rainy season on farmer's upland field at Malang, East Java Indonesia (112°.37'41" East, 7o.58'40" South). The location has a distinct wet and dry season, with the average annual rainfall of about 2,200 m, and the rainy season starts in November and ended on April of the following year. The weather conditions during the experiment were presented in Table 1 .

Table 1 The weather condition during experimental periods

Weather variables	November	December		January		February		March	
	Week 3-4	Week 1-2	Week 3-4	Week 1-2	Week 3-4	Week 1-2	Week 3-4	Week 1-2	Week 3-4
Rainfall (mm)	233	308	166	256	276	178	102	112	98
Tempetarure (°C)	24.2 (18 - 38)	23.8 (18 – 32)	23.5 (19 – 28)	24.4 (19 – 32)	25.1 (19 – 32)	25.1 (19-33)	25.4 (20 – 33)	25.3 (19 -33)	23.4 (20 – 33)
Relatif Humidity (%)	76 (60 – 85)	85 (72 – 88)	87 (70 – 89)	85 (71 -90)	80 (66-90)	76 (65 – 85)	70 (62 – 80)	72 (60 – 80)	70 (65 – 76)
Lighting duration (%)	65 (19 – 90)	70 (40 – 90)	70 (10 – 90)	51 (10 – 70)	56 (16 – 68)	60 (20 – 70)	76 (40 – 86)	74 (55 – 90)	82 (60 – 90)
Radiation (cal/cm^2)	329 (48 – 488)	320 (48–547)	310 (45-498)	320 (56-430)	306 (61-374)	325 (20-433)	320 (40 -450)	330 (56-490)	336 (60-520)
Pan evaporation (mm)	4.2 (0.9 – 5.2)	4.2 (0.8-6.3)	4.2 (1.2-6.3)	3.8 (1.2-5.2)	3.6 (0.8-5.8)	4.6 (1.4-5.8)	5.2 (1.8-5.4)	5.1 (1.4-5.6)	5.6 91.6-5.8)

*) the values in the bracket are minimum and maximum values

The experimental treatments tested in this study consisted of 4 levels planting date and 2 levels harvesting time. These 4 levels of planting dates were: (i) planting at the commencement of rainy season, (ii) at 2 weeks, (iii) at 4 weeks, and (iv) at 6 weeks after the commencement of rainy season. The harvesting time employed was: (i) 85 % maturity, (ii) 100 % maturity, and (iii) post maturity). These 12 treatment combinations were arranged in a randomized Block Design with 3 replications. The soybean pod was considered as mature if 90 % the fruit pod already changed from green color to yellowish and the placenta already drop from the pod.

Two soybean seeds/hole, Wilis cultivar, was planted on a plot size of 5 X 4 m with plant distance of 25 X 25 cm. At one week after planting the plants were thinned to be 1 plant/hole. The soybean plant was fertilized with 100 kg/ha urea, 50 kg/ha super-phosphate, and 50 kg/ha KCl; all of these fertilizers were given at the planting date. Pest and diseases was done by spraying the crops with Benlate and Agrothion 50 EC, 4 cc/l which done since 2 weeks after planting until flowering with interval of one week.

Data collected plant height, time of flowering, time of 85 % fruit mature, time of 100 % fruit mature, time of post mature, number of total pods, number of filled pods, number of seed/pod, 100 seed weight, seed yield, water content at harvest time, and water content after sun dried, seed protein content and seed carbohydrate content. Protein was determined by micro-Kjeldahl method, and carbohydrate content was determined by the method of AOAC [10].

A laboratory experiment was set up to study seed quality from point of view of planting materials. This was designed by studying the effect of time of storage on seed germination and the treatments were 3 storage times, i.e.: 1 month, 2 months, and 3 months. Fifty seeds were germinated on whattman filter paper in a Petri dish; each treatment was done in 4 replications.

RESULTS AND DISCUSSION

It was observed that that the maximum plant height and leaf area was obtained at 8 weeks measurement. However, plant height and plant biomass still increased up to 10 weeks observation . It seems that after 8 weeks the old leaves were falling down, so that the number of leaf was relatively constant. Therefore, the data presented in Table 2 were that of 8 weeks observation for leaf number and leaf area, and

10 weeks observation for dry biomass, the result presented in Table 2 show, in term of plant height, leaf number, leaf area and dry biomass, that planting date significantly influenced the growth of soybean planted in rainy season. In general delaying planting date of rainy soybean restricting plant growth, so that the dry biomass and other observed parameter of these plans was lower compared to that of planted at the beginning of rainy season.

Table 2 Effect of planting date on plant height, leaf number, leaf area, net assimilation rate and dry biomass of soybean planted in rainy season

Planting date	Plant height at 10 weeks (cm)	Leaf number at 8 weeks leaf/plant	Leaf area at 8 weeks (cm^2/plant)	Dry biomass at 10 weeks (g/plant)	Net assimilation rate at 8 weeks (mg/cm^2/day)
The commencement of rainy season	118.21 a	101.45 a	2042.89 a	35.69 a	0.38 a
2 weeks after the commencement of rainy season	117.12 a	96.40 a	1832.21 b	28.16 b	0.25 b
4 weeks after the commencement of rainy season	83.52 b	78.63 b	1394.42 c	16.34 c	0.19 c
6 weeks after the commencement of rainy season	84.94 b	80.65 b	1485.92 c	16.63 c	0.18 c

1) means followed the same letters in the same column are not significantly different (p=0.05)

Looking the weather condition presented in Table 1, it can be suggested that the lowering of plant growth with delaying the planting date could be due to the lower of lighting duration. Lighting duration will influence plant assimilation, and it has been widely known that soybean is one of the plant species that sensitive to day length [11]. In tropical region, such as Indonesia, although day length is not varied much, lighting duration can vary due to weather condition (see Table 1). Another reason for lower soybean growth with delaying planting could be thought due to the higher soil water content, and probably soil temperature. Traditional farmers, with their long experience, have already known that delaying planting time will harm their crops. In their term the soil is "cool". From point view of physiological process, the lowering of plant growth with delaying planting date is caused by the decrease of assimilation (Table 2). In addition to lighting duration, the lower assimilation rate of soybean planted at several weeks after the commencing of rainy season surely was due to a lower leaf area.

The result in Table 2 also show delay planting date up to 2 weeks after the start of the rainy season did not significantly influenced plant height, but a further delay of planting date significantly lowered plant height. Leaf number, leaf area and plant biomass; on the other hand, has already decreased at the 2 weeks planting date delay. The lower of plant biomass at planting date 2 weeks after the commencement of rainy season (compared to the soybean planted at the commencement of rainy season) was thought to be caused by the falling down of some old leaves.

Planting date significantly influenced relative growth rate (RGR) of soybean planted in the rainy season (Table 4). The results presented in Table 3 show that planting date influence soybean RGR at early growth only (until 8 weeks). Delay planting date from 4 weeks to 6 weeks after the beginning of rainy, However, did not significantly influenced the RGR of soybean planted in the rainy season. It seems that, the low growth rate at the early growth phase can be compensate at the late growth phase

Table 3 The effect of planting date on relative growth rate (RGR) of soybean planted in the rainy season

Treatments	Relative Growth Rate (g/g/day)		
	0-2 weeks	2- 8 Weeks	8-10 Weeks
The commencement of rainy season	0.09 a	0.09 a	0.06
2 weeks after the commencement of rainy season	0.07 ab	0.08 ab	0.07
4 weeks after the commencement of rainy season	0.06 b	0.08 ab	0.07
6 weeks after the commencement of rainy season	0.05 b	0.06 b	0.07 NS

1) Means followed the same letters in the same column are not significantly different (p=0.05)

Postpone planting date of rainy soybean several weeks after the commencement of rainy season delay time of flowering and time of maturity, but did not significantly influence the duration of flowering time (Table 4). The flowering time of the soybean soon after the commencement of rainy season was 39 days after planting. Delaying planting 2 weeks after the commencement of rainy season become longer, but a further delay did not significantly influenced time of flowering (compared to 2 weeks delayed planting date). Delaying planting the rainy soybean 2 weeks after the commencement of rainy season prolong the maturity time from 101 days to 104 days.

Table 4 The effect of planting date on time of flowering, duration of flowering, number of flowers, number of pods and time of maturity of soybean planted in the rainy season

Planting date	Time of flowering (days after planting)	Duration of flowering (days)	Number of flowers/plant	Number of total pods/plant	Time of 85% maturity (days after planting)	Time of 100% maturity (days after planting)	Time of 85% maturity (days after planting)
The commencement of rainy season	39.66 b	11.55	137.88 a	115.80 a	96.00 b	101.00 b	106.33 b
2 weeks after the commencement of rainy season	47.66 a	11.22	102.91 b	88.22 b	100.66 a	104.00 a	110.07 a
4 weeks after the commencement of rainy season	46.66 a	11.55	96.36 bc	88.35 b	101.00 a	104.33 a	110.00 a
6 weeks after the commencement of rainy season	46.33 a	11.35 NS	86.27 c	75.28 d	102.66 a	104.00 a	110.66 a

1)means followed the same letters in the same column are not significantly different (p=0.05)

The results presented in Table 4 also show that delaying planting date of rainy soybean decrease the number of flowers and the total number of pods. Soybean planted at the beginning of rainy season produced 137.88 flowers/plant with total pod number of 115.80 pods/ plant, and that of planted at 2 weeks later produced only 102.92 flowers/plant with 88.22 pods/plant.

The experimental result given in Table 5 show that planting date and harvesting time significantly influence the number of harvested pods and soybean seed yield, but did not significantly influenced number of seeds/pod. It seems that the number of seed/pod is more influenced by genetically properties of rather than environmental condition.

Table 5 Effect of planting date and harvesting time on yield component and seed yield of soybean planted in the rainy season

Treatment		Number of harvested pods	Number of seeds	Seed yield
Planting date	Harvesting time (%mature)	(pod/plant)	(seed/pod)	(Mg ha^{-1})
Commencement the rainy season	85	73.60 abc	2.04	1.94 abcd
	100	76.50 ab	1.98	2.14 ab
	Post mature	89.66 a	2.00	2.25 a
2 weeks after commencement the rainy season	85	51.16 def	2.05	1.87 bcd
	100	58.63 cde	2.04	2.01 abc
	Post mature	63.13 bcd	1.95	2.12 ab
4 weeks after commencement the rainy season	85	65.27 bcd	2.01	1.72 cde
	100	64.20 bcd	2.03	1.69 de
	Post mature	54.40 def	1.96	1.57 ef
6 weeks after commencement the rainy season	85	41.63 f	1.97	1.34 fg
	100	49.40 def	1.92	1.27 fg
	Post mature	45.17 ef	2.00 NS	1.14 g

1) means followed the same letters in the same column are not significantly different (p=0.05)

Furthermore, the result given in Table 5 show that delaying harvesting time of rainy soybean did not significantly influence seed yield of soybean planted at the beginning of rainy season or 2 weeks later. However, delaying harvesting time significantly decreased seed yield of the rainy soybean if I was planted 4 and 6 weeks after the beginning of rainy season.

Planting date and harvesting time significantly influenced water content of harvested seed and carbohydrate content of soybean seed planting in the rainy season (Table 6). Carbohydrate content decreased with delaying planting date and increased with delaying harvesting time. Carbohydrate in any plant is result assimilation processes, and therefore carbohydrate content will be higher in the plant with a higher assimilation rate. The results in Table 2 show that assimilation rate decrease with delaying planting date, and thus it is reasonable that delaying planting date decreased seed carbohydrate content. A similar explanation can be given to the increase of carbohydrate with delaying harvesting time, because delaying harvesting time would give more time for assimilation, and hence increase assimilation rate.

The increase in water content of harvested soybean seed with delaying planting date might be due to the impact of the environmental condition during soybean growth as well as at the harvest time. The data

given in Table 1 show that relative humidity and soil water content were higher for the soybean planted at several weeks after the commence of the rainy season. The decrease in water content of soybean seed with delaying harvesting time is logic consequence of seed maturity processes.

Table 6 Effect of planting date and harvesting time on soybean seed quality planted in the rainy season

Treatment		Water content of harvested seed	Water content of sun dry seed	Protein content	Carbohydrate content
Time of planting	**Harvesting time (%mature)**	**(%)**	**(%)**	**(%)**	**(%)**
The commencement the rainy season	85	28.83 b	20.14	33.95	15.97 ab
	100	25.36 d	19.46	34.59	17.29 a
	post mature	20.64 e	18.86	33.00	16.66 a
2 weeks after commencement the rainy season	85	28.38 bc	18.70	35.58	14.23 b
	100	25.35 d	19.67	33.73	18.17 a
	post mature	21.01 e	18.16	33.64	17.26 a
4 weeks after commencement the rainy season	85	30.93 a	19.37	33.85	12.32 c
	100	26.70 cd	18.81	32.22	16.27 ab
	post mature	22.59 e	18.84	34.18	13.26 c
6 weeks after commencement the rainy season	85	31.64 a	18.62	33.89	12.31 c
	100	26.45 cd	18.27	33.75	16.23 ab
	post mature	21.56 e	18.38	34.17	14.25 bc
			NS	NS	

1) means followed the same letters in the same column are not significantly different (p=0.05)

Furthermore, the results in Table 6 show that water content of sun dry seed and protein content did not significantly influenced by planting date and harvesting time. It seems that protein content is more genetically controlled.

The results in Table 6 show that planting date and harvesting time significantly germination rate. Delaying planting date, in general decreased germination rate. At germination test done soon after harvesting (0 month), the soybean planted at the beginning of rainy season had a germination rate of 100 %, whereas that of planting 4 weeks after the beginning of rainy season had germination rate from 90 % (harvested at post mature condition) to 96 % (harvested at mature condition). The significant effect of soybean harvesting date on seed quality and viability had also been demonstrated by Nangju [12].

The rate of germination would be influence by carbohydrate content in the seed. As shown in Table 6, carbohydrate content of soybean seed planted in the rainy season decreased with delaying planting time. Therefore, it is reasonable that germination rate of soybean seed planted in the late of rainy season would be lower. The same explanation can be used for the low germination rate of soybean seed harvested at 85 % maturity.

Table 7 Effect of planting date and harvesting time of rainy season soybean on the germination rate

Treatment		Seed germination (%) at various time of storage (months after harvesting)			
Time of planting	Harvesting time (%mature)	0	1	2	3
The commencement the rainy season	85	100 a A	98 a A	92 ab AB	90 a B
	100	100 a A	100 a A	94 a A	94 a A
	Post mature	100 a A	100 a A	94 a AB	90 a B
2 weeks after commencement the rainy season	85	98 a A	90 b AB	82 cd B	86 ab AB
	100	100 a A	98 a A	86 bc B	76 ab C
	Post mature	98 a A	96 a A	80 d B	80 ab B
4 weeks after commencement the rainy season	85	98 a A	86 bc B	80 d B	70 b C
	100	100 a A	86 bc B	86 bc B	72 b C
	Post mature	100 a A	84 c B	82 cd B	70 b C
6 weeks after commencement the rainy season	85	98 a A	84 c B	80 d B	68 b C
	100	98 a A	86 bc B	72 e B	64 b C
	Post mature	100 a A	84 c B	72 e C	70 b C

*) means followed by the same letters for the same time of measurements, at the same column (small letters) and rows (capital letters) are not significantly different (p=0.05)

The results presented in Table 7 also show that the rate of germination decreased as the seed was stored for a longer time. However, until 2 months of storage the rate of germination was not significantly different with that of freshly harvested, and until 3 months of storage the germination rate was still 90% or more. For the soybean planting 4 weeks and 6 weeks after the beginning of rainy season, on the other hand, seed germination decreased significantly since the one month storage.

CONCLUSIONS

The experimental results discussed above show that the growth of the rainy soybean was influenced by planting date. The yield as well as seed quality of rainy soybean were significantly influenced by planting date and harvesting time. To obtain a high yield and good quality seed, the plant should be planted not later than 2 weeks after the commencement of the rainy season. The seed of these treatments had higher carbohydrate content, and a more stable seed germination rate. Delayed planting date was not only decrease the yield, but also decrease seed quality which result in rapid decrease of germination rate.

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