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Evaluation of adaptable genotypes and its factors associated with seed yield of late planted soybean

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Summary

Evaluating the adaptability of soybean to late sowing (short photoperiod) is an important strategy to increase seed yield in low latitude areas and southwestern Japan where optimal sowing date faces various problems. We investigated the yield potentiality by late sowing using the world mini-core collections (*GmWMC*) including 82 genotypes and evaluated what factors are related to seed yield. Soybean seeds were planted on 4 August in 2015 at the experimental field of Saga University, Japan. The dates of emergence and first flowering (R1), the start of seed filling (R5), beginning maturity (R7), seed yield and some yield relating parameters at R8 stage were recorded using five randomly selected plants. The average values of photoperiod and temperature were 14.08 h and 26.75℃ from first emergence to the average date of flower open. The days from emergence to first flower open (DEF), days of R1−R5 (first flower open to start of seed filling), days of R5−R7 (seed filling), and days of emergence−R7 (whole growing period) varied from 18−50 d, 12−37 d, 13−40 d, and 63−107 d, respectively. Seed weight plant^{-1} varied from 1.4−39.5 g. Seed weight plant^{-1} was significantly correlated with DEF and days from emergence to R7, whereas insignificantly correlated with the days from R1−R5 and days from R5−R7. Moreover, seed weight plant^{-1} showed positive correlation with some vegetative growth parameters, i. e. node number in main stem, total node number in plant, stem height, stem weight, and number of branches in plant. Some genotypes i. e. Karasumame (Naihou) (39.53 g plant^{-1}), Chiengmai Palmetto (28.80 g plant^{-1}), Local Var. (Tegineneng) (25.68 g plant^{-1}) and Manshuu Masshok (25.47 g plant^{-1}) produced higher seed weight plant^{-1} compared to the average seed weight (14.15) of whole genotypes; these genotypes have delayed flowering and large vegetative growth. These results indicated that delayed flowering and larger vegetative growth could increase seed yield in late sowing under short photoperiod.

Keywords: Adaptability, Genotypes, Late sowing, Soybean, Yield

Introduction

Soybean (*Glycine max* (L.) Merr.) is an important protein and oil rich crop. Besides, it is also good source of high value secondary co-product such as isoflavone, lecithin, vitamins, nutraceuticals and anti-oxidant. Consequently, the demand of soybean has been increasing all over the world gradually for its multiple uses, i.e. human foods, animal feeds and industrial products. Therefore, it is necessary to increase soybean seed yield and areas for keeping pace with growing demand.

Soybean is very familiar crop in southwestern Japan, which is commonly sown early- to mid-July. However, the emergence and seedling standing are harmed by excessive soil moisture cause of rainy season (Zheng and Watabe, 2000; Nakayama et al., 2004; Hamada et al., 2007; Yamashita et al., 2008). Late sowing is a preference to avoid this harm of rainy season in Southwestern Japan. Conversely, most of the soybean genotypes give less vegetative mass in late sowing consequently low seed yield due to short day length. An attempt to increse seed yield in late sowing by selecting potential genotypes and development of new genotype through breeding program would be positive approach.

Several previous experimental studies were conducted to avoid rainy season in southwestern Japan. Uchikawa et al. (2009) reported that yield reduction could be minimized by sowing soybean during end of July in Northern Kyushu island Japan. Umezaki et al. (1996) also reported that some late-maturing genotypes (Akisengoku, Hyuga, Asomusume) provide high yield even those were planted in early or mid August in Miyazaki (southern Kyushu). Fatichin et al. (2013) reported that seed yield under late sowing in southwestern Japan could be improved by selecting genotypes based on larger seed number or longer seed filling periods. However, few studies have been published about the adaptibility to late sowing using wider genotypic background.

Another major concern is that early flowering in soybean is caused by short day length (Board and Settimi, 1986; Zhang, 2006) or joint effect of short day length and high temperature (Board and Hall, 1984) during the vegetative periods. This early flowering diminish the vegetative mass and ultimately provide low seed yield (Boerma and Ashley, 1982). Besides, photoperiod is shorter, and temperature is higher in low latitude areas. Consequently, most of the soybean genotypes initiate flower earlier and produce low seed yield. Higher yield potential genotypes under short photoperiodic condition (late sowing) is an option to overcome low productivity in low latitude areas.

From the above background, it was essential to screen the genotypes for improving soybean seed yield under late sowing, therefore the objective of present study was to evaluate the adaptability of the soybean world mini-core collections (*GmWMC*) including 82 genotypes and investigate what factors affect the seed yield in late sowing.

Materials and methods

Plant materials and growth conditions

Eighty-two genotypes of the soybean world mini-core collections (*GmWMC*) provided by the National Agriculture and Food Research Organization (NARO), Japan gene bank were planted on 4 August 2015 in the experimental field at Saga University, Saga of Japan (33° 14'32" N and 130° 17'28" E). The collections consist of a wide variation in the origin, maturing earliness, and some other growth habits. Five seeds were sown in each hill (5 hills / genotype), which were arranged at 20 cm interval with 70 cm row spacing. A basal chemical fertilizer, at a rate of $N:P_2O_5:K_2O=3:10:10$ gm^{-2}, and agricultural lime (100 gm^{-2}) were applied before plowing. Seedlings were thinned into two plants per hill when the first trifoliate leaf appeared. Weeding was done by hand tractor or hand and pesticide was applied when necessary.

Measurement and data collection

Photoperiod and temperature

Daily photoperiodic hours were recorded from sunrise to sunset according to Saga weather station; and 30 min each was added before sunrise and after sunset. Daily average temperature was measured at a standard weather station located approximately 100 m from the experimental field.

Phenological stages

The date of emergence (50% of plants with cotyledons above soil surface), first flowering (50% of plants with one flower at any node, R1), the start of seed filling (seed in 3 mm long in a pod on one of the four uppermost nodes on the main stem, R5), and beginning maturity (one pod anywhere with its mature color, R7) were determined according to Fehr et al. (1971).

Measurement of seed yield and components at full maturity (R8)

Node number in main stem, total node number per plant, main stem height, dry stem weight after removing pods, number of branches showing over two node and one-hundred-seed weight were recorded for five randomly selected plants and average value of these were used for statistical analysis.

Statistical analysis

The Pearson correlation coefficients with significant level were measured by using data analysis tool of Microsoft Excel (version 2016).

Results

Daily photoperiodic hours and mean air temperature for the whole growing season are shown in Fig. 1. The average value of photoperiod and temperature were 14.08 h and 26.75℃ during the period from Aug. 8 (first genotype emergence) to Sep. 9 (the average date of flower initiation).

Table 1 shows the variation of origin, duration of different growth stages and seed yield plant^{-1} among the *GmWMC* genotypes. The days from emergence to first flower open (DEF), days of R1−R5 (first flower open to start of seed filling), days of R5−R7 (seed filling), and days of emergence−R7 (growing period) varied from 18−50 d, 12−37 d, 13−40 d, and 63−107 d respectively. The seed weight plant^{-1}differed greatly from 1.4−39.5 g. Moreover, there was no relation between origin of genotypes and seed weight plant^{-1} (Table 1).

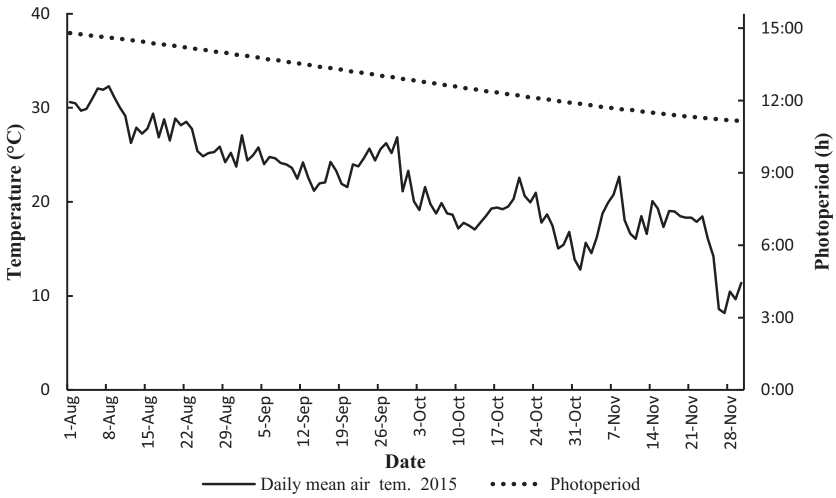

Fig. 1. Daily photoperiod and mean air temperature during experiment time in 2015.
Source: http://www.nao.ac.jp/

Fig. 2 shows the relationships between seed weight plant^{-1}and duration of each growth stages. The seed weight plant^{-1}was significantly correlated with DEF ($r=0.61$, $p<0.001$) and whole growing period ($r=0.50$, $p<0.001$) (Fig. 6 A and D), however was not correlated with duration from first flower open to start of seed filling ($r=0.17$, $p>0.05$) and seed filling period ($r=-0.12$, $p>0.05$) (Fig. 2 B and C).

Fig. 3 shows the relationship between seed weight plant^{-1} and various yield relating parameters at R8 stage in soybean *GmWMC* genotypes. Seed weight plant^{-1} was positively correlated with total node number plant^{-1} ($r=0.66$, $p<0.001$), number of branch ($r=0.59$, $p<0.001$), node number in main stem ($r=0.59$, $p<0.001$), stem height ($r=0.55$, $p<0.001$), and stem weight ($r=0.53$, $p<0.001$), indicating seed weight plant^{-1} was clearly related with vegetative growth. Moreover, 100 seed weight was not associated with seed weight plant^{-1} ($r=0.00$, $p>0.05$).

Soybean genotypes such as Karasumame (Naihou) (39.53g plant^{-1}), Chiengmai Palmetto (28.80g plant^{-1}), Local Var. (Tegineneng) (25.68g plant^{-1}), Manshuu Masshok (25.47g plant^{-1}) and Java 5 (24.9g plant^{-1}) produced higher seed weight plant^{-1} compared to the average seed weight (14.15) of whole genotypes (Table 1). These genotypes hold large total node number plant^{-1} such as 137 in Karasumame (Naihou), 54 in Chiengmai Palmetto, 44 in Local Var. (Tegineneng), and 50 in Java as well as late flowering character (Table 1 and Fig. 3).

Discussion

Applying the soybean genotypes adapted under late sowing condition (short photoperiod) is the possible way to avoid seedling damage from rainy season in southwest-

Table 1. Origins, duration of different growth stages and seed weight in *GmWMC*.

ID number	Genotypes	Origin	DEF (d)	R1−R5 (d)	R5−R7 (d)	E−R7 (d)	SW (g)	100 SW (g)
*GmWMC*001	Fiskeby V	Sweden	18	18	27	63	5.4	23.28
*GmWMC*006	Ks 1034	Malaysia	21	15	28	64	9.3	28.00
*GmWMC*011	Seita	Rep. Korea	24	14	40	78	6.4	28.58
*GmWMC*012	Manshuu	China	23	18	30	71	5.8	19.12
*GmWMC*014	Kls 203	Rep. Korea	40	25	25	90	11.8	17.93
*GmWMC*015	Chuuhoku 2	Rep. Korea	25	15	29	69	5.8	6.40
*GmWMC*018	Rigai Seitou	China	39	23	18	80	15.3	12.18
*GmWMC*019	Chousenshu (Cha)	Korea	23	21	21	65	3.4	8.64
*GmWMC*020	Pochal	Taiwan	28	17	32	77	16.2	23.01
*GmWMC*022	Nezumi Meta	Korean Peninsula	38	13	28	79	–	–
*GmWMC*024	Chieneum Kong	Rep. Korea	24	17	29	70	3.8	16.29
*GmWMC*027	Kongnamul Kong	Rep. Korea	23	19	29	71	9.3	17.34
*GmWMC*029	Shirosota	korean Peninsula	28	18	25	71	15.3	20.19
*GmWMC*035	Pekin Dai Outou	China	24	17	31	72	5.9	9.27
*GmWMC*036	Masshokutou (Kou 502)	China	24	20	28	72	1.4	7.90
*GmWMC*038	Ichiguuhou	China	36	24	19	79	17.8	17.03
*GmWMC*042	Masshokutou (Kou 503)	China	24	20	21	65	3.9	6.38
*GmWMC*045	Okjo	Rep. Korea	25	19	35	79	15.1	26.80
*GmWMC*046	Ke 32	Philippines	22	20	23	65	7.8	17.80
*GmWMC*048	Heamnam	Rep. Korea	38	18	21	77	18.0	14.78
*GmWMC*066	Heukdaelip	Rep. Korea	24	24	33	81	10.7	17.84
*GmWMC*070	Choyoutou	China	–	–	–	–	–	–
*GmWMC*071	Pk 73−54	India	25	14	40	79	8.9	20.94
*GmWMC*072	M 581	India	31	18	26	75	14.9	17.71
*GmWMC*073	Uronkon	Korean Peninsula	25	14	39	78	8.8	27.65
*GmWMC*075	Cheongye Myongtae	Rep. Korea	22	15	31	68	8.9	27.24
*GmWMC*083	Keumdu	Rep. Korea	29	15	34	78	6.0	18.75
*GmWMC*084	Peking	China	26	17	26	69	4.5	11.93
*GmWMC*086	Anto Shoukokutou	China	22	21	24	67	5.4	11.11
*GmWMC*089	Bongchunbaekjam	China	23	18	28	69	14.9	22.90
*GmWMC*094	Jeokgak	Rep. Korea	31	18	25	74	15.7	24.33
*GmWMC*103	Senyoutou	China	40	22	20	82	19.1	14.35
*GmWMC*107	Hakka Zashi	China	24	24	21	69	7.7	23.64
*GmWMC*108	Karasumame	China	32	21	21	74	17.0	10.62
*GmWMC*113	Baritou 3 A	Indonesia	27	19	31	77	16.4	25.50
*GmWMC*115	Williams 82	USA	25	24	24	73	19.1	19.72
*GmWMC*118	Oudu	Rep. Korea	23	29	32	84	5.2	13.61
*GmWMC*119	Hakubi	China	24	20	29	73	14.4	22.91
*GmWMC*120	U 1416	Nepal	33	16	31	80	7.1	10.23
*GmWMC*122	Gapsanjaelae (I)	Rep. Korea	23	29	24	76	15.7	18.95
*GmWMC*123	N 2295	Nepal	34	12	29	75	19.4	20.46
*GmWMC*125	Bhatmas	Nepal	36	12	29	77	20.0	20.48
*GmWMC*129	Aoki Mame	China	37	12	34	83	12.5	15.89

ID number	Genotypes	Origin	DEF (d)	R1−R5 (d)	R5−R7 (d)	E−R7 (d)	SW (g)	100 SW (g)
*GmWMC*132	L 2a	Philippines	30	23	24	77	27.1	19.83
*GmWMC*136	Local Var (Seputih Raman)	Indonesia (Sumatra)	44	20	13	77	22.6	8.05
*GmWMC*138	Col/Pak/1989/Ibpgr/2326 (1)	Pakistan	27	25	27	79	16.8	10.44
*GmWMC*141	Petek	Indonesia	37	24	18	79	15.2	9.18
*GmWMC*142	Java 5	Indonesia	50	20	24	94	24.9	13.32
*GmWMC*143	M 44	India	33	17	29	79	13.8	16.79
*GmWMC*144	M 918	India	37	19	31	87	24.7	17.96
*GmWMC*146	Hm 39	India	35	19	31	85	19.4	16.01
*GmWMC*147	Col/Thai/1986/Thai−78	Thailand	36	18	32	86	22.9	21.04
*GmWMC*148	M 42	India	36	23	33	92	−	−
*GmWMC*150	U 1042−1	Nepal	35	20	31	86	6.5	6.14
*GmWMC*151	Java 7	Indonesia	35	19	25	79	13.8	10.50
*GmWMC*152	U 1290−1	Nepal	38	17	22	77	24.4	21.39
*GmWMC*154	Manshuu Masshokutou	China	35	29	25	89	25.5	12.32
*GmWMC*156	U 8006−3	Nepal	33	29	24	86	10.6	7.52
*GmWMC*159	Col/Pak/1989/Ibpgr/2323(2)	Pakistan	25	28	27	80	8.2	8.91
*GmWMC*160	N 2392	Nepal	48	37	22	107	5.6	7.16
*GmWMC*162	Col/Thai/1986/Thai−80	Thailand	38	21	31	90	21.8	17.72
*GmWMC*163	N 2491	Nepal	46	24	34	104	23.5	13.38
*GmWMC*165	Karasumame (Shinchiku)	Taiwan	32	23	21	76	14.1	9.28
*GmWMC*166	Merapi	Indonesia (Sumatra)	44	23	22	89	16.2	7.79
*GmWMC*168	L 317	India	42	24	23	89	20.9	9.85
*GmWMC*169	Hakuchikou	China	24	21	30	75	9.4	22.86
*GmWMC*170	M 652	India	36	24	30	90	6.8	6.91
*GmWMC*171	U−1741−2−2 No.3	Nepal	32	33	25	90	15.8	9.60
*GmWMC*173	Karasumame (Naihou)	Taiwan	47	16	36	99	39.5	8.21
*GmWMC*175	Bishuu Daizu	China	32	22	26	80	19.3	17.23
*GmWMC*176	Sandek Sieng	Cambodia	46	22	26	94	14.9	8.90
*GmWMC*181	Chiengmai Palmetto	Thailand	36	26	18	80	28.8	13.33
*GmWMC*182	Local Var. (Tegineneng) Purple Flower	Indonesia (Sumatra)	47	20	23	90	14.2	6.34
*GmWMC*182	Local Var. (Tegineneng) White Flower	Indonesia (Sumatra)	40	26	30	96	25.7	12.99
*GmWMC*183	Karasumame (Heitou) Yellow Seed	Taiwan	26	20	29	75	9.8	21.38
*GmWMC*183	Karasumame (Heitou) Black Seed	Taiwan	32	22	22	76	10.5	10.76
*GmWMC*186	Ringgit	Indonesia (Sumatra)	44	24	21	89	15.8	7.34
*GmWMC*187	Kadi Bhatto	Nepal	37	31	−		8.5	5.54
*GmWMC*188	E C 112828	India	46	24	23	93	23.0	6.53
*GmWMC*190	San Sai	Thailand	48	30	−	−	21.5	8.84
*GmWMC*191	Miss 33 Dixi	Philippines	68	−	−	−	−	−
*GmWMC*192	U 1155−4	Nepal	37	31	20	88	19.8	6.17

DEF is the days from emergence to first flower open, R1−R5 is the days from R1 to R5, R5−R7 is the days from R5 to R7, E−R7 is the days from emergence to R7, SW is the seed weight plant^{-1} and 100 SW is the 100 seed weight. The genotypes are arranged based on ID number.

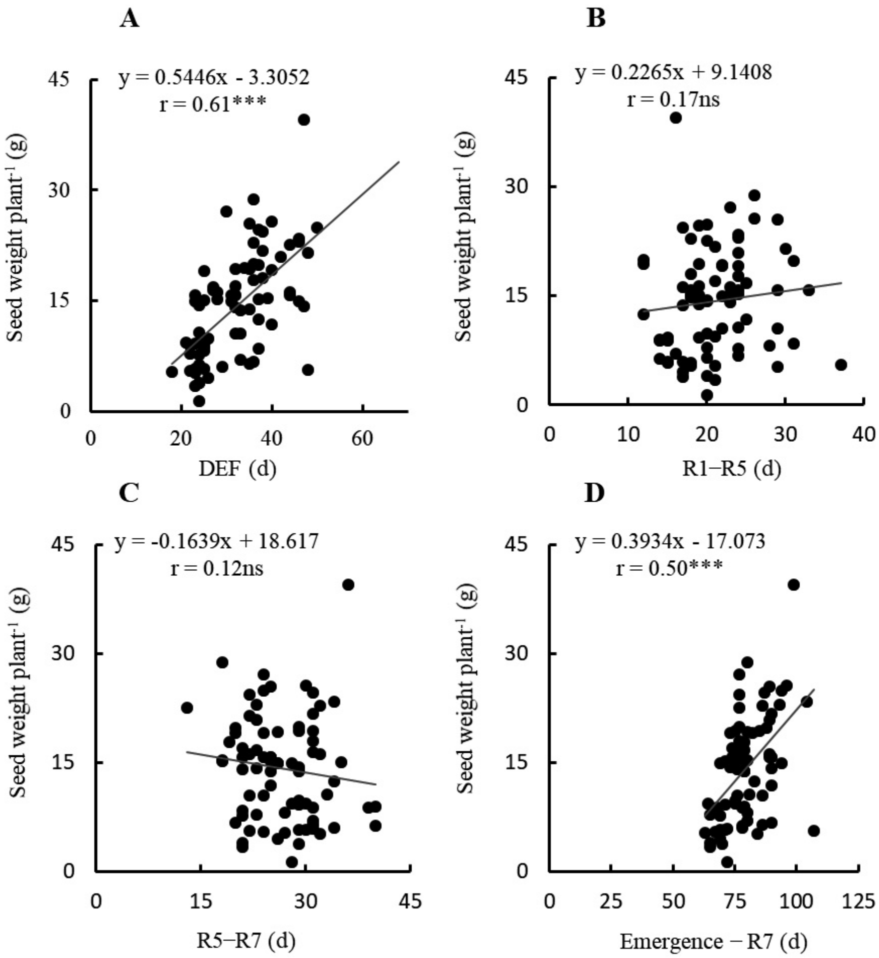

Fig. 2. Relationship between seed weight plant^{-1} and the duration of each growth stages. A. the days from emergence to first flower open (DEF); B. days from R1–R5 (first flower open to start of seed filling); C. days from R5–R7 (seed filling); D. days from emergence –R7 (whole growing period).*** and ns denote significant at $P<0.001$ and not significant ($P>0.05$), respectively.

ern Japan and to increase seed yield in low latitude areas. Board (2002) reported that a 29–276% increase in soybean seed yield through suitable genotype selection based on vegetative growth for late sowing in Rouge, Louisiana, USA (30° N), which is similar in latitude with Kyushu island in southwestern Japan. Broad et al. (1997) also reported that pod per reproductive node (node after flowering) is the potential trait for genetic improvement of late sowing soybean in Baton Rouge, USA. Accordingly, it is considerable that there is a tremendous opportunity to improve soybean production in the southwestern Japan by selecting suitable genotypes. The present study was conducted to identify the best suited trait for high seed yield in late sowing under short photoperiod.

Flowering and post flowering duration stages are the most important components

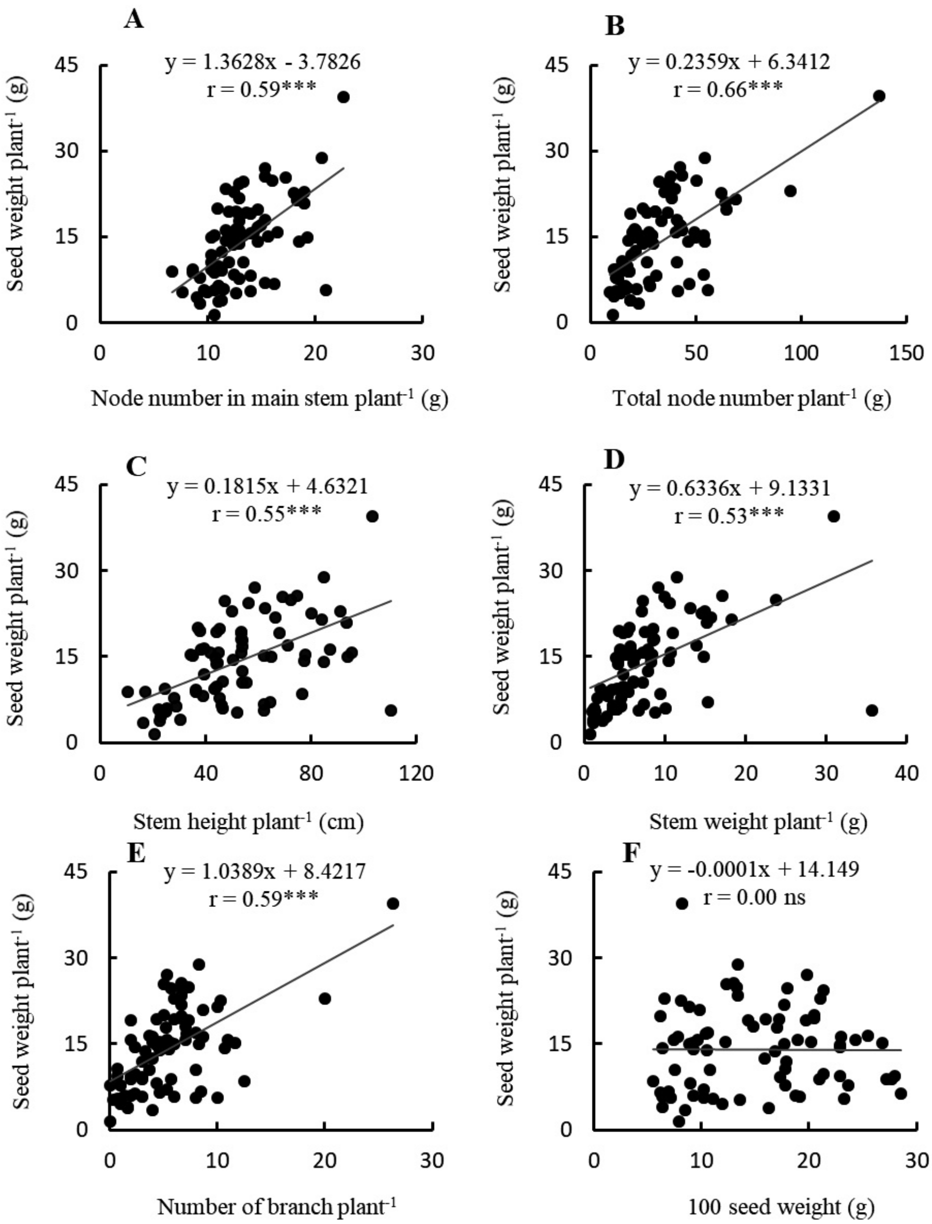

Fig. 3. Relationship between seed weight plant^{-1} and other yield related characters. A. node number in main stem plant^{-1}; B. total node number plant^{-1}; C. stem height plant^{-1}; D. stem weight plant^{-1}; E. number of branch plant^{-1}; F. 100 seed weight. *** and ns denote significant at P<0.001 and not significant (P>0.05), respectively.

responsible for seed weight. Present study pointed out that seed weight plant^{-1}was significantly related with DEF (Fig. 2 A), whereas insignificantly related with duration from first flower open to start of seed filling (Fig. 2 B). Baig et al. (2017) similarly found that days from emergence to flowering is strongly associated with seed weight per plant in soybean. Alternately, days from flowering to start of seed filling (R1−R5) is not associated with seed weight (Akhanda et al., 1981). Moreover, in our study days of seed-filling period showed insignificant correlations with the seed weight plant^{-1} (Fig. 2 C). However, days of seed-filling period is positively correlated with seed weight based on previous reports (Gay et al., 1980; Hanway and Weber, 1971; Nelson, 1987; Smith and Nelson, 1986). It was also found that seed weight plant^{-1}was positively correlated with whole growing period (Emergence to R7) (Fig. 2 D). Besides, considering the correlation coefficients of the days of each growth stages with seed weight, it indicated that days from first flower open to end of seed filling (R1−R7) was not associated with seed weight plant^{-1}.

Some vegetative growth relating parameters (node number in main stem, total node number in plant, stem height, stem weight, and number of branches) showed significant and positive correlation with seed weight plant^{-1} (Fig. 3). Considering these results, it could be stated that larger vegetative growth before flowering would be used as selection criteria for the improvement of soybean seed weight plant^{-1}in late sowing.

Soybean *GmWMC* genotypes showed a wide variation (1.4−39.5g) in seed weight plant^{-1}in late sowing under short photoperiodic condition. However, some genotypes, i.e. Karasumame (Naihou), Chiengmai Palmetto, Local Var. (Tegineneng), Manshuu Masshok and Java 5 exhibited higher seed weight plant^{-1} compared with average seed weight plant^{-1} of whole genotypes (Table 1) even in late sowing under short photoperiodic condition; these genotypes may adapt to low latitude areas. Moreover, the demand for soybeans has been increasing in low latitude areas (short photoperiod) as a major protein resource. It is also well known that soybean production in low latitude areas face many problems, including short photoperiod, drought, and high temperature. The growth period is shortened with short photoperiod and high temperature due to earlier flowering time, therefore produces lower seed yield. Above mentioned high seed yield genotypes could be desirable genotypes to increase seed yield for those areas.

In conclusion, the results revealed that late flowering genotypes produced large vegetative growth and higher seed weight plant^{-1} in soybean *GmWMC*, suggesting seed weight plant^{-1} of soybean could be enhanced by selecting genotypes in the late sowing based on longer DEF and larger vegetative growth.

Acknowledgments

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