The effects of sowing date on fatty acid synthesis of rapeseed (*Brassica napus* L.)

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Abstract

Taking Huashuang No.3, Huaza No.6, Zhongshuang No.9, Zhongyou 821 (Brassica napus L.) as trial materials, sowing dates ranging from the beginning of September to the beginning of November impact on the growth and development of rapeseed plant and the fatty acid synthesis. The results showed that different sowing dates mainly made for rapeseed growth and development, and development of flower and fruit under a different temperature condition, and then influenced the synthesis of fatty acid and protein. Grain number per pod and oil content were declined when the average temperature was above 24°C in flowering period. On the same growing condition, oil content (%) was related to accumulated temperature from initial flowering to maturity as 4%-10%, 10%-30%, 30%-40% corresponding 300°C-400°C, 400°C-550°C, 550°C-750°C respectively.

Key words: rapeseed, *Brassica napus* L., sowing date, fatty acid synthesis

1 Introduction

It has been quite important to make sure optimum sowing date in rapeseed planting and production. Chinese people have accumulated abundance experiences on these aspects, maybe for thousands of years. But nowadays, definition of sowing date and our research fields are altered profoundly. These changes have been listed as follows: The growing regions, technique of production and management practices become quite different; Temperature, sunlight and humidity conditions alter a lot due to sowing date. The sowing date can also influence growing stages, vegetative and reproductive development, characteristics of dry matter accumulating and distributing, diversity in yield and quality and so on.

Previous studies on sowing date were focused on final yield and yield components. There were accordant results, such as sowing early could improve leaf area and photosynthesis of plant ontogeny, prolong leaf functional period and enrich number of flowers and pods; And it also could produce higher dry matter of per plant and thus contributing to yield. But there were few researches about sowing date effect on quality of rapeseed especially on oil concentration, and even some researches conducted different results. On the base of normal sowing date, sowing earlier did benefit to oil content (W.E. May 1994, Zhang et al.2005), but Hakan Ozer(2003) revealed an opposite result when sowing spring rapeseed in April and May in Turkey. In the trial of sunflower sown from 11 April to 1 May conducted by WU Chun-Sheng, seed oil were both higher in early and late sowing date, therefore he considered there was no direct relationship between seed oil content and growing days, but environmental factors such as day temperature (differences in temperature between day and night included), solar radiation and rainfall affect a lot. Temperature may be the dominant matter.

Studies on temperature effect have revealed numerous results, 15°C-20°C or bigger differences in temperature between day and night made for increasing oil content. 16.5°C may be the best for lodging(Lian et al, 1967), when the daily mean temperature is 21°C-22°C, lodging slowed down and maturity sped up. When the maximal temperature was above 20°C-25°C at maturity phase of rapeseed, seed oil content would be reduced (Niu et al, 1987). But principles about how temperature affects oil content and oil components are still not clear. In this article, we studied growing course, fatty acid accumulation course and weather factor alternation effects, and elicited some conclusions.

2 Materials and methods

A two growing season-experiment was carried out at agricultural experiment and research centre, Huazhong Agricultural University in Wuhan during the growing seasons 2001-2002 and 2005-2006. In this study, five winter rapeseed cultivars Huashuang No.3, Huaza No.6, Zhongshuang No.9, Zhongyou 821 (*Brassica napus*.L) were applied. These cultivars were provided by Huazhong Agricultural University and Oil Crops Research Institute of Chinese Academy of Agricultural Sciences.

The study was conducted with a randomized complete block design. The area of each plot was 10 m^2, 4m long and 2.5m apart. The final density was 15cm*33cm. fertilizers were applied to the field with P_2O_5 (120kg/hm^2), Compound fertilizer (187.5kg/hm^2), Urea (75kg/hm^2) and Boron fertilizer(4kg/hm^2). Six different sowing dates was established,2 Sep(SD1), 11 Sep(SD2), 25 Sep(SD3), 10 Oct(SD4), 31 Oct(SD5), 15 Nov(SD6), and rapeseed were transplanted about one month later after each sowing during 2001 and 2002. In 2005, seeds were sown directly to the field on 1 Sep(SD1), 16 Sep(SD2), 1 Oct(SD3), 16 Oct(SD4), 31 Oct(SD5), 15 Nov(SD6), with an interval of 15days. In 2005-2006 growing season,SD1, SD2 and SD3 were harvested on 8 May, SD4 and SD5 were harvested on 10 May, SD6 on 14 May.

Table 1. The growing stage of rapeseed in different sowing dates(2001-2002, Huashuang No.3, d/m)

Sowing dates	Seeding	Transplant	Pre-flowering	Early flowering	Peak flowering	End flowering	Harvest
SD1	2/9	4/10	5/1	27/2	11/3	20/3	28/4
SD2	11/9	16/10	10/1	28/2	12/3	23/3	28/4
SD3	25/9	24/10	4/2	3/3	14/3	25/3	28/4
SD4	10/10	13/11	12/2	10/3	21/3	1/4	7/5
SD5	25/10	24/12	19/2	12/3	23/3	3/4	7/5
SD6	12/11	19/2	27/2	17/3	8/4	16/4	21/5

The time of seeding, pre-flowering, early flowing, peak flowing, maturity and harvest phases were investigated and noted. About 50-100 Pods which grew from base main stem of 10 plants were signed at peak-flowering time. Seed oil content was determined by Soxhlet apparatus. Results for each year were analyzed separately, because sowing dates differed between the two growing seasons and were presented by individual year.

Temperature, sunlight, rainfall and other weather data during rapeseed growing period were collected from weather bureau of Hubei province.

3 Results and discussion

3.1 Changes of growing course in different sowing dates

The whole growing stage was shortened as sowing date was delayed (table 1). In the study, SD6 had 49 day-shorter than SD1. Pre-flowering and maturity phases were postponed as sowing date was delayed, great difference occurred in pre-flowering period. This period of SD1 was 35 days longer than SD6, it was 2.9 times.

SD1 and SD2 had relative shorter seeding stage among different sowing dates, SD2 had shortest seeding stage. Sowing on 25 Sep (SD3) had got the longest seeding stage and it would be reduced as the delayed sowing date when sown after 10 Oct. There were no significant differences in flowering stage among sowing dates, flowering phases in anterior five sowing date were all at 21 to 23 days. SD6 showed a longer stage 30 days (table 2).

Table 2. Changes of development days in different sowing dates(2001-2002, Huashuang No.3, d)

Treatments	Seeding	Pre-flowering	Flowering	Maturity	Whole stage
SD1	126	53	21	38	238
SD2	121	49	23	36	229
SD3	132	27	22	36	217
SD4	125	26	22	36	209
SD5	117	21	22	34	194
SD6	107	18	30	35	189

3.2 Temperature changes between growing stages in different sowing dates

In the view of climatic variety, the temperature would gradually reduce in prophase growth of rapeseed, but slowly rise in phase of seed formation. The accumulated temperature in whole stage of rapeseed decreased incessantly in September as the sowing date was postponed. The accumulated temperature of last five sowing dates had reduced 220°C, 366°C, 201°C, 221°C, 19°C degrees respectively compared with its anterior stage (table 3) and 366°C was the top.

Both sunlight and temperature could influence the length of seeding stage. Comparing each growing phase we found that accumulated temperature and average temperature at seeding stage reduced along with the postponed sowing dates. The seeding stage of SD1 and SD2 suffered lower temperature and enough sunlight condition from November to December, and showed trend of pre budding. Average temperature in seeding stage from SD3 to SD6 decreased obviously. However different treatments went through the phase when sunlight changed from short to long in midwinter in December, SD3 had a longest seeding stage due to the change, and seeding stages of SD4, SD5 and SD6 were shortened in turn.

In pre-flowering stage, accumulated temperature decreased and average temperature increased among different treatments except SD6. Data in table 2 and table 3 showed that pre-flowering stage was shortened as average temperature expended. Accumulated temperature and average day temperature influenced the time when rapeseed went into early flowering stage. When temperature stabilized above 5°C it begin to bud, and budding would be accelerated as temperature stayed above 10°C (Liu-Houli, 1987). Comparing SD5 and SD6, author considered the upper limit temperature was 226°C to 228°C on the condition that average temperature must be above 10°C.

Accumulated temperature in flowering stage increased as sowing date postponed. Average temperature showed the similar trend. But these changes in SD1 and SD2 were not so obvious. The proper temperature range for flowering was 12°C-20°C, and 14°C-18°C was optimum. In our study, temperature in flowering stage of anterior five sowing dates was within the range, 1 or 3 days gap may exist in special. But flowering stage of SD6 was from 17 Mar to 20 Apr, the average temperature from 31 Mar to 4 Apr (after early flowing) and 13 Apr to 15 Apr was all above 20°C in 2002, and in 2 Apr it reached the top 30.6°C. Flowering began to reduce even cease along with the raising temperature, when temperature went down it went on flowering. SD6 had fewer flower in peak flowering stage than other treatments for the change.

Maturity period of anterior five sowing dates was all completed in April, in SD6 it completed in the last ten-day of April or in the middle ten-day of may. Temperature changes in April 2002 was quite large, an abnormal low temperature 20°C appeared in the middle ten-day of May. Therefore average temperature among treatments had no significant rules. Sowing early showed a lower temperature in maturity phase, but sowing late was on the contrary. Thus accumulated temperature deceased along with the postponed sowing date.

Table 3 Changes of average temperature in different stage of different sowing time(2002, ℃)

treatments	Seeding		Pre-flowering		Flowering		Maturity		Whole stage ACT
	ACT	AVT	ACT	AVT	ACT	AVT	ACT	AVT	
SD1	1896	15.1	458	8.6	291	13.9	644	16.9	3289
SD2	1722	14.2	422	8.6	315	13.7	611	17.0	3069
SD3	1531	11.6	272	10.1	314	14.3	586	16.3	2703
SD4	1262	10.1	269	10.3	352	16.0	620	17.2	2502
SD5	1067	9.1	228	10.8	365	16.6	572	16.8	2231
SD6	862	8.1	235	13.0	560	18.7	556	17.9	2212

ACT- accumulated temperature, AVT- average temperature

3.3 Changes of oil content in different sowing dates

In the course of fatty acid accumulation showed in fig.1, each sowing date exhibited a rapid increasing period. Whereas the period continued much longer when sowing early, in other words, rapeseed could complete the course of fat transformation and accumulation in relative short time if sowing date was delayed. Oil content moved up faster under high temperature condition in the forepart of oilseed formation.

Comparing six sowing dates, oil content may have 4 percents gap among different sowing dates. Oil content reached the top 43.90% and 43.91% respectively in SD1 and SD5, but oil content was much lower up to 39.95% in SD1 which was sown earlier, thus there was no direct relationship between oil content standard with sowing dates.

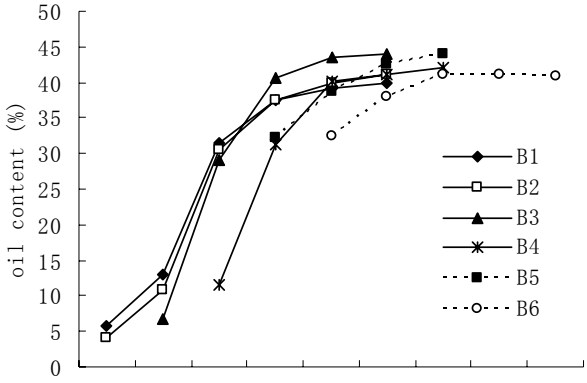

Fig.1 Fat accumulate of different sowing date

Trails in 2006 also elicited similar results, different cultivars had different growing stages, thus showed different response to sowing dates. Zhongshuang No.6 and Zhongyou 821 which two cultivars were more obvious among cultivars applied in the trail have rapid growing rates and got a higher oil content as sowing date advanced when they were in the treatments from SD1 to SD4. But they didn't keep to the rule when sowing date was put off to SD5 and SD6. Huashang No.3 and Huaza No.6 got the maximal oil content in SD3.

Table 4 Changes of oil content in different varieties in different sowing date (2006, %)

Cultivars	SD1	SD2	SD3	SD4	SD5	SD6
HuashuangNo.3	43.06	44.04	46.38	39.49	37.35	41.24
Zhongshuang No.6	44.07	39.86	38.74	38.32	40.79	40.76
Zhongyou 821	47.51	44.27	41.87	38.27	44.07	40.13
Huaza No.6	41.92	40.90	45.27	41.26	40.44	37.91
Average	44.14	42.27	43.07	39.34	40.66	40.01

3.4 The correlation between oil content and climate factors in different sowing dates

Results mentioned above revealed that early sown rapeseed could get into maturity stage more quickly, and it was not determined by maturity phase but determined by environmental and growing conditions before maturity stage. Material accumulation in early phases impacted formation of seedcase, transformation of dry materials at first and then affected oil concentration.

Relative analysis in table 5 showed different levels of oil content among sowing dates. These distinctions were determined by the accumulation of average temperature from pre-flowering stage to maturity stage. Relative coefficient got up to 0.978 and was significant. The correlation between oil content and accumulated temperature from pre-flowering to flowering stage was significant and the coefficient was 0.890; But there was no relationship between temperature from flowering to maturity and oil content. When the temperature of each growing stage was considered respectively, we found lower relativities, but correlation between accumulated temperature in pre-flowering stage and oil content got maximum, maturity got second and flowering stage at last. It indicated that material which was accumulated in pre-flowering stage mostly influenced oil synthesis. Oil content was determined by temperature in pre-flowering stage and temperature when rapeseed grew into maturity. Temperature in pre-flowering and early flowering stage had negative correlation with oil content,

it also indicated lower average temperature did favor to oil accumulation.

Sunlight in pre-flowering stage had negative correlation with oil content, in other words, more sunlight hours mean higher temperature. Accumulated temperature in pre-flowering stage got negative correlation with oil content. Average rainfall in pre-flowering stage had positive correlation with oil content, but accumulated rainfall showed little relationship, it indicated that well-proportioned rainfall could make for fatty acid synthesis. The average rainfall in early flowering showed negative correlation. Abundance rainfall may influence blooming and seeding, and then influence oil content.

Table 5 Correlation coefficient between rapeseed oil content and climatic factor (2002)

	Seeding	Pre-flowering	Early flowering	Peak flowering	Maturity
AAT	-0.325	**-0.655**	-0.192	0.011	-0.483
AVT	**0.937****	**-0.792**	**-0.744**	0.045	-0.104
ADF	-0.174	**0.669**	**-0.714**	0.229	0.246
ASH	-0.170	**-0.762**	-0.388	0.392	-0.173
	Whole stage	Seeding to flowering	Pre-flowering to maturity	Pre-flowering to flowering	Flowering to maturity
AAT	-0.510	-0.519	**-0.978****	**-0.890***	-0.400

*, ** significant at the 0.05 and 0.01 level respectively. For each main effect, values within columns followed by the same letter are not significantly at P_/0.05. CV, coefficient of variation; AAT-average accumulated temperature, AVT-average temperature, ADF-average day rainfall, ASH-accumulated sunlight hours.

Different growing seasons may build various temperature conditions and growing stages among cultivars, and these changes could influence fatty acid synthesis. The relative analysis between accumulated temperature and oil content in 2006 showed positive correlation in seeding stages of 4 cultivars, especially in Zhongyou 821 and Zhongshuang No.6, a significant correlation came up. The positive correlation also exhibited in pre-flowering stage in Huashuang no.3, but negative in other 3 cultivars; Temperature in maturity and whole growing stage showed positive correlation. The result distinct with that in 2002 had made us found the accurate relationship between temperature and oil accumulation, but large amount data was required to make sure the limit temperature when rapeseed went through a growing stage to another and corresponding temperature parameters (table 5).

Table 6 Correlation coefficient between oil content and accumulation temperature in different cultivars (2006)

	Seeding	Pre-flowering	Flowering	Maturity	Whole stage
HuashuangNo.3	0.807	0.476	-0.247	0.530	0.789
Zhongshuang No.6	0.914	-0.510	0.719	0.925	0.922
Zhongyou 821	0.965	-0.791	-0.626	0.890	0.962
Huaza No.6	0.806	-0.188	0.389	0.569	0.792

Seed oil content and temperature accumulation course have been summarized into table 7 and table 8, results showed that temperature accumulated after early flowering was the key parameter for oil content; Oil content could reach 4%-10% when temperature was accumulated up to 300°C-400°C after early flowering; oil content kept on increasing to 30%-40%, when temperature accumulated to 850°C-900°C, then oil content got to the top. If temperature went on moving up, the influence on oil content could be reduced.

Table7 Changes of accumulated temperature from early flowering to sampling time in different sowing dates(°C)

Treatment	Sampling(d/m)								Correlated coefficients
	21/3	30/3	6/4	13/4	20/4	28/4	7/5	21/5	
SD1	312.8	433.5	584.7	697.6	820.8	944.0			0.937**
SD2	303.9	424.6	575.8	688.7	811.9	935.1			0.946**
SD3	274.3	395.0	525.9	638.8	762.0	885.2			0.910*
SD4	205.6	326.3	457.2	570.1	693.3	816.5	969.3		0.908*
SD5		291.2	422.1	535.0	658.2	781.4	934.2		0.924
SD6		207.5	338.4	451.3	574.5	697.7	850.5	1095.3	0.847

*, ** significant at the 0.05 and 0.01 level respectively. For each main effect, values within columns followed by the same letter are not significantly at P_/0.05. CV, coefficient of variation.

Table 8 Changes of oil content in different sowing dates(%)

	21/3	30/3	6/4	13/4	20/4	28/4	7/5	21/5
SD1	5.67	12.91	31.43	37.41	39.10	39.95		
SD2	4.07	10.80	30.47	37.61	40.02	41.20		
SD3		8.68	29.18	40.53	43.43	43.90		
SD4			11.49	31.31	38.23	41.80	41.97	
SD5				32.25	38.76	43.56	43.91	
SD6					32.55	38.00	40.70	40.87

Rapeseed could complete maturity on April sooner or later among sowing date treatments in the study, and most of time under the identical temperature condition. We had found SD3 and SD5 developed at the period with the similar temperature condition and oil content was much higher. So the author considered these changes revealed the close relationship between oil accumulation and temperature before maturity. Or we could say in the stage from pre-flowering to maturity, plants in different sowing dates may go though distinct temperature condition and result in different metabolize, therefore accumulation and function of seedcase were determined and oil content gap was established at last.

When comparing active accumulated temperature of SD3 and SD5 from pre-flowering to maturity, we found oil content in other four sowing dates was higher than SD3 and SD5. Average temperature in pre-flowering period of SD3 and SD5 were 10.1°C, 10.8°C (table 2), were placed in the middle not the lowest; and the temperature in maturity were 16.3°C, 16.8°C, that's on the low side. Thinking over all indexes above, we got some deduction as follows: average day temperature around 10°C-11°C in pre-flowering stage could balance vegetative growth and reproductive growth, temperature around 16°C-17°C may make for export of material in seedcase and fatty acid accumulation. The accumulated temperature altered from 1150°C to 1200°C did benefit to material transformation and fatty acid synthesis.

4 Conclusions

There is a 70 days gap among sowing dates from September to November, and this could make whole growing stage of rapeseed short, especially for the pre-flowering stage. Rapeseed sowed from 2 Sep to 25 Oct had approximate flowering stage, but when sowing date was postponed to 12 Nov, temperature at the beginning of flowering reached above 24, it brought up several changes such as flowering time was prolonged obviously, pod development, the course of physiological metabolize, material accumulation and quality formation was fastened, these brought down oil content. 4 percents changes came up due to treatment of sowing date.

Oil content in different sowing date was mostly determined by the temperature accumulated from pre-flowering stage to maturity. Lower average temperature in pre-flowering and early flowering stage could make for oil accumulation. Average temperature around 10°C-11°C in pre-flowering stage could balance vegetative and reproductive growth. When average temperature arrived at 16°C-17°C in maturity stage oil accumulation would be promoted. Temperature accumulated after flowering stage related with oil synthesis: Oil content could reach 4%-10% when temperature was accumulated up to 300°C-400°C after early flowering; Oil content kept on increasing to 30%-40%, when temperature was accumulated to 850°C-900°C, and then oil content got to the top.

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