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USING BBCH SCALE AND GROWING DEGREE DAYS TO IDENTIFY THE GROWTH STAGES OF WINTER OILSEED RAPE GENOTYPES IN THE SKOPJE REGION

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Abstract

Identifying the growth stages on oilseed rape accurately is essential for effective crop management. Two commonly used methods for identifying growth stages are growing degree days (GDD) and BBCH scale, by measuring the heat accumulation on daily temperatures and describes the growth stages of plants. The main goal of this research is using a combination of these methods, where can identify the growth stages in production period. The three-year field experiments 2015/16 - 2017/18 were located in the Skopje Region, with two genotypes in 30 variants and 4 replications. Sowing was on October 1, with 8 kg ha^{-1} seeding rate. BBCH scale for oilseed rape was used to register the stages of development. Growing degree days - GDD were determined by the formula with corrections for Tmax and Tmin values calculated. Germination (09 BBCH), was 7 days in the first and third year and 79 ^{0}C - 65 ^{0}C GDD and 8 days in the second year - 65 ^{0}C GDD. The flowering (63 BBCH), begins at 202 days in the first, - 809 ^{0}C GDD, 199 days in the second year – 649 ^{0}C GDD, and 198 days third year with 633 ^{0}C GDD. Senescence (BBCH 97), began on days 254, with accumulate 1530 ^{0}C GDD, days 258 – 1577 ^{0}C GDD, and days 265 with 1542 ^{0}C GDD in 3, 1 and 2 years. All data obtained from the research are aimed at meeting the needs of producers and researchers related to rapeseed production in order to ensure optimal production.

Key words: *oilseed rape, GDD, BBCH-scale, heat accumulation, temperatures*

INTRODUCTION

The development of oilseed rape from the emergence of cotyledons to the flowering stage is controlled by photo-thermal factors and temperature from flowering to full maturity (Nanda et al., 1995). In winter genotypes, the initial stages of development, including sprouting, leaf development, and stem elongation, last the longest in terms of time (in days). When conditions are optimal, temperature is the main factor on which the dynamics of germination and sprouting of plants depends. At temperatures below 10°C, germination is slow (Ehrensing, 2008), which is why seed yield is often limited as a result of initial poor plant growth (Yang et al., 2014). From the beginning of leafs development formation to the end of the stem elongation stage, the timing of individual stages is controlled by temperature, vernalization stage, and photoperiodism (Böttcher et al., 2016). The optimal temperatures for the growth and development of oilseed rape (photosynthesis, vegetative, and generative stages) have been determined to be between 21-25°C (Deligios et al., 2013). The Skopje Valley is located in the Vardar region, in which a modified Mediterranean type of climate prevails (Filipovski et al., 1996), or a dry, cold semi-arid climate (BSk) according to the Köppen-Geiger climate classification (Beck, et al. 2018).

MATERIAL AND METHODS

In a three-year research, the stages of development were represented by their occurrence and duration, presented in days. Due to the simultaneous entry of plants into the stages for the entire period of vegetation, results were shown that applied to both genotypes respectively. The BBCH oilseed rape scale was used to register them (Weber & Bleiholder, 1990). Meteorological data were provided by Macedonian Hydrometerological service, from the free database Reanalysis data NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, and as well from the wunderground database. Sowing was done on October 1, with a sowing rate for both genotypes of 8 kg ha^{-1}. Two genotypes of oilseed beet were used (variety Zorica, hybrid Rohan). The sum of active temperatures was obtained as a product of the average monthly temperatures and the number of days in the month during the vegetation period of the genotypes. The sum of GDD - growing degree days was determined from the values of the daily maximum and minimum temperatures and the base temperature, which for oilseed rape is 5 ºC, during the vegetation, from the beginning to the end of development, according to the formula (Gordon and Bootsam 1993): GDD = (Tmax + Tmin) / 2 - Tbase (Tmax: daily maximum temperature, Tmin: daily minimum temperature, Tbase: base temperature (5 °C) (Vigil et al. 1997). In the calculation of GDD, if the maximum daily temperature exceeds 30 °C, the value for Tmax is corrected to 30 °C, while if the daily minimum temperature falls below 5 °C, the value for Tmin is corrected to 0 °C (Djaman et al. 2018).

RESULTS AND DISCUSSION

Development Stages according to BBCH scale

The stage of germination and sprouting in the first and third year was seven days, in the second eight days, data which is also confirmed in the research of Ferguson (2015). According to this research, under favourable agroecological conditions, sprouting occurs in seven days.

From germination to the appearance of two true leaves, plants took 7 and 8 days (I II and III year). In both genotypes, the appearance of four true leaves was ascertained on the 28th day from sowing in the year I and II and on the 30th day in the year III. In substage the four to six leaf substage was recorded on the 48th day in the first vegetation year, the 49th in the day second, and the 46th day in the third. The plants entered the leaf development stage with nine or more leaves formed in 86 days in the first, 85 days in the second, and 79 days in the third vegetation year. If the plants do not have sufficiently formed leaves before the onset of the winter months, the low temperatures and low light intensity during the winter can cause serious losses of the above-ground mass, and thus of the accumulated nitrogen, as well as of the leaf area index (Colnenne et al. 1998, Sierts et al. 1987).

The plants entered the stem elongation stage and the substage of two visible internodes in 167 days in the first, 168 days in the second, and 165 days in the third year, with a time difference of 81, 83, and 86 days after the leaf development stage.

The formation of flower buds in an inflorescence (visible flower buds green bud), started after the 178th day in the first, 177th day in the second, and 175th day in the third year, so that in the second substage, when the buds turned yellowish, the plants entered 8 or 10 days later.

The beginning of the flowering substage, when 30% of the flowers were opened, began on the 202nd day in the first, 199th day in the second, and 198th day in the third year of research, while the mass flowering substage was registered on the 207th day in the first, 211th day in the second, and 204th day in the third year. This stage is the most critical in the development of oilseed rape due to the reduction of total leaf area and reduced photosynthesis (Gabrielle et al.,1998; Robelin and Triboli, 1983). Minus temperatures at the beginning of flowering affect the intensive differentiation of plants, flowering lasts longer and fewer weakly developed fruits are formed on the lower branches (Balodis and Gaile 2016). On the other hand, intense rains in the flowering stage of the plant can have a negative effect on seed yield and, despite the formation of a larger biomass during flowering (Takashima et al., 2013). If there is a lack of water in the period after flowering in oilseed rape, the seed yield will be lower as a result of intensive transpiration and the inability of the plants to meet the required amounts of water (Weymann et al. 2015).

The substage when 80% of the fruits were ripe and when the seeds acquired a black color began on day 251 in the first, day 259 in the second, and day 248 in the third year. In the seed formation stage, temperature has a significant influence on the yield potential (Balodis and Gaile, 2016).

Table 1. Stages of development and length of vegetation period (in days).

Stages description	BBCH	stages and substages - days					
		2015/16		2016/17		2017/18	
Germination			7		8		7
Emergence: cotyledons emerge through soil surface	09	7		8		7	
Leaf developmen			7		7		8
2 leaves unfolded	12	14		15		15	
			14		13		15
4 leaves unfolded	14	28		28		30	
			20		21		16
4 to 6 leaves unfolded	18	48		49		46	
			38		36		33
9 or more leaves unfolded	19	86		85		79	
Stem elongation			81		83		86
2 visibly extended internodes	32	167		168		165	
Inflorescence emergence			11		9		10
Flower buds visible from above ("green bud")	51	178		177		175	
			9		8		10
First petals visible, flower buds still closed ("yellow bud")	59	187		184		185	
Flowering			15		15		13
30% of flowers on main raceme open	63	202		199		198	
			5		12		6
Full flowering: 50% flowers on main raceme open	65	207		211		204	
			7		8		6
End of flowering	69	213		219		210	
Development of fruit			7		7		7
50% of pods have reached final size	75	220		226		217	
			6		6		7
Nearly all pods have reached final size	79	226		232		224	
Ripening- seed			20		21		18
50% of pods ripe, seeds dark and hard	85	246		253		242	
			5		6		6
80% of pods ripe, seeds dark and hard	88	251		259		248	
			7		6		6
Senescence - Plant dead and dry	97	258		265		254	
Harvest			6		6		7
Length of vegetation period		264		272		261	

The potential yield can be finally determined at the end of the flowering stage, but whether it will be achieved or not to a large extent depends on the temperature and the availability of water in the successive stages of crop development (Weymann et al. 2015).

From the sub- stage 80% ripe fruits in the ripening stage, the plants entered for 7 or 6 days. The ripening stage began on day 258 in the first, day 265 in the second, and day 254 in the third year.

The length of the vegetation period for the winter genotypes of oilseed rape ranged from 260 to 310 days (Димов, 2014; Mustapić, 1982). Represented by years in the first year of the research, the length of the vegetation period was 264 days, in the second 272 days, and in the third year 261 days for both genotypes (Table 1).

Table 2. Days stages/vegetation, sum on GDD ^{0}C stages/substages and vegetation.

Year	2015/16			2016/17			2017/18		
Stages description (BBCH Code)	Days stages/ vege.	GDD (^{0}C) stages	GDD (^{0}C) vege.	Days stages/ vege.	GDD (^{0}C) stages	GDD (^{0}C) vege.	Days stages/ vege.	GDD (^{0}C) stages	GDD (^{0}C) vege.
Germination / Emergence cotyledons emerge through soil surface (09)	7/ 7	79	79	8/8	67	67	7/7	65	65
Leaf development									
2 leaves unfolded (12)	7/14	72	151	7/15	52	119	7/15	65	130
9 or more leaves unfolde (19)	72/ 86	231	382	70/85	190	309	64/79	199	329
Stem elongation 2 visibly extended internodes (32)	81/167	162	543	83/168	98	406	86/165	87	416
Inflorescence emergence (51-59)	11/178	32	575	9/177	76	482	10/175	35	451
Flowering									
30% of flowers on main raceme open (63)	24/202	234	809	22/199	168	649	23/198	183	633
Full flowering (65)	5/207	40	849	12/211	72	721	6/204	76	699
Development of fruit									
50% of pods have reached final size (75)	13/220	100	949	15/226	175	896	13/217	160	762
Nearly all pods have reached final size (79)	6/226	66	1015	6/232	72	968	7/224	267	966
Ripening – seed									
50% of pods ripe, seeds dark and hard (85)	20/246	235	1250	21/253	292	1260	18/242	255	1220
80% of pods ripe, seeds dark and hard (88)	5/251	75	1325	6/259	100	1360	6/248	97	1317
Senescence plant dead and dry (97)	7/258	104	1429	6/265	89	1449	6/254	106	1423
Harvest time	6/264	102	1530	7/272	128	1577	7/261	119	1542
Vegetation length / Total GDD	264	1 530		272	1 577		261	1 542	

Growing degree days GDD - Accumulated sum of effective temperatures

The phenological development of plants is linked to the level of temperature or thermal accumulation, or the base temperature above which active growth begins in most plants. Temperature is an important factor that provides for the growth and development of plants, although it is conditioned by other climatic factors (humidity, solar radiation, day length, etc.) (Iljovski, 2012). The temperature effects on plant development are observed through the measurement of the sum of effective temperatures (GDD) or accumulated heat and temperature of the culture over a certain period of time/stage. In the Skopje Valley, annual sums of temperatures are 4410 ^{0}C (Filipovski et al., 1996), of which, based on the results from this research and the length of the winter oilseed rape vegetative period, 35% account for the total accumulated effective temperatures. The need for satisfactory effective temperatures is especially

In the development stage of two true leaves and the beginning of leaves development formation, the plants entered for approximately 14 and 15 days, with accumulated 151 GDD ^{0}C, 119 GDD ^{0}C and 130 GDD ^{0}C. For 13-16 days from sowing, the required accumulated temperature in the research of Martinez-Feria (2015) ranges from 129-156 ^{0}C, which coincides with our research both in calendar days and accumulated temperature. Wittman (2005) in (Arizona, USA) determined 237-314 GDD ^{0}C, while Miller et al., (2018) from 282-324 GDD ^{0}C. Martinez-Feria (2015) reported that from emergence to development of the five-leaf stage, 323 and 374 GDD ^{0}C were accumulated, which in our research coincided with the formation of 9 leaves (19 BBCH) in the first and third vegetative years, in which GDD amounted to 382 ^{0}C and 329 ^{0}C, sums that had significance in the development of the plants for overwintered. According to Estonian conditions, the best wintering of oilseed rape was obtained when sowing was done on August 15, ant the plants had accumulated 416 GDD ^{0}C at the end of the five-leaf stage. At early (August 8) and late sowing (August 29), the plants accumulate 500 GDD ^{0}C and 300 GDD ^{0}C, and only 50% of the plants overwintered (Lääniste et al. 2007). These findings were confirmed in our research, in which in the second vegetative year, when the genotypes accumulated the lowest

expressed in the stages of development: germination, onset of flowering and full maturity (Balodis et al., 2011). The number of days from sowing to germination is relatively identical, with accumulated effective temperatures amounting to 79 GDD ^{0}C (year I), 67 GDD ^{0}C (year II) and 65 GDD ^{0}C (year III). The values obtained were lower than those of Martinez-Feria (2015), who, upon sowing on October 1 in 2012, for this stage established 129 GDD ^{0}C, while in 2013, 156 GDD ^{0}C. Somewhat higher values of 152-186 GDD ^{0}C were determined in Montana USA in the period 1995-1998 (Miller et al. 2018). On the other hand, in conditions in Lithuania, upon sowing of September 1, the GDD value for the final stage of flowering in the first year (2009) was 60 GDD ^{0}C, and 38 GDD ^{0}C in 2010, (Balodis & Gaile, 2011). Data on required GDD for early stages of autumn genotypes of Brassica napus indicate a requirement of 90 to 115 ^{0}C, obtained with a base temperature (Tbase) of 4 ^{0}C (Vigil et al. 1997).

amount of only 309 GDD ^{0}C in the five-leaf stage and 406 GDD ^{0}C in the stem elongation stage, the percentage of plants that did not overwinter was the highest (17.8%).

Already in the formation stage of flower buds (inflorescences) for the year II, the GDD sum (482 GDD ^{0}C) was equal to that of the year III (451 GDD ^{0}C), but both years had registered lower sums compared to the year I (575 GDD ^{0}C), due to the high average monthly (8.4 ^{0}C) and average monthly maximum (14.8 ^{0}C) temperatures in February that year.

In the flowering stage and the substage of 30% fully open flowers, the plants accumulated effective temperatures of 809 GDD ^{0}C (year I), 649 GDD ^{0}C (year II), and 633 GDD ^{0}C (year II). This condition is maintained in the full flowering substage with 849 GDD ^{0}C - year I, 721 GDD ^{0}C - year II, 699 GDD ^{0}C - year III. The high values in the first year are the result of high average monthly and maximum temperatures in February (8.4 ^{0}C, 14.8 ^{0}C) and March (8.1 ^{0}C, 14.1 ^{0}C). According to other research, for this stage and substage 50 % flowering accumulated effective temperatures range from 759 to 852 ^{0}C (Miller et al. 2018), but also higher GDD sums, 1153-1218 GDD ^{0}C - year I and 1259-1322 GDD ^{0}C - year II (Begna and Angadi 2016), differences in GDD values which are obtained due to the location.

In the flowering stage, accumulated effective temperatures are stabilisate, and approximately the same amounts of 1250 GDD ^{0}C, 1260 GDD ^{0}C, and 1220 GDD ^{0}C (I, II and III year) were obtained. In the same stage, another research (Miller et al. 2018) shows slightly higher effective temperatures from 1326 to 1445 GDD 0C.

Finally, the sums of accumulated effective temperatures for the genotypes yielded 1530 ^{0}C, 1577 ^{0}C, and 1542 ^{0}C (I, II and III year), obtained values that are close to another research where GDD ranges from 1432 to 1557 ^{0}C (Miller et al. 2018), but also lower than the 2283 GDD ^{0}C obtained in research with a longer vegetation (sowing early September - harvesting mid/late July) (Djaman et al. 2018). The impact of temperature conditions in the year as key factors that determine the values of accumulated effective temperatures has great importance for the development of the oilseed rape during the respective stages or for the entire period of vegetation.

CONCLUSION

In a modified Mediterranean-type climate, or dry, cool semi-arid climate (BSk) the accumulated sum of effective temperatures for a significant stages are: from 119 to 151 GDD ^{0}C for stages leaf development and substage 2 leaves (12 BBCH), 406 to 543 GDD ^{0}C for substage 2 visibly extended internodes (32 BBCH), 575 GDD ^{0}C emergence stages to flowering, 633 to 809 GDD ^{0}C for flowering or 30% of flowers on main whol open (63 BBCH), 762 to 949 GDD ^{0}C for 50% of pods to reach final size (75 BBCH), from 1220 to 1260 GDD ^{0}C in stage 50% of pods ripe, seeds dark and hard (85 BBCH) and 1530 to 1577 GDD ^{0}C for the vegetation period. Displaying and identifying growth stages using the BBCH scale in combination with growing degree days (GDD) we believe will be important and useful for producers of winter oilseed rape genotypes.

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УПОТРЕБА НА BBCH СКАЛАТА И GDD МЕТОДОТ ЗА ИДЕНТИФИКАЦИЈА НА УПОТРЕБА НА BBCH СКАЛАТА И GDD МЕТОДОТ ЗА ИДЕНТИФИКАЦИЈА НА ФАЗИТЕ НА РАСТ НА ЗИМСКИ ГЕНОТИПОВИ МАСЛОДАЈНА РЕПКА ВО СКОПСКИОТ РЕГИОН

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Резиме

Идентификувањето на фазите на раст на маслодајната репка е од суштинско значење за ефикасно управување. Два често користени методи за идентификација на фазите и степенот на раст, BBCH скалата и GDD, се корисни за мерење на акумулираната топлина од дневните температури и опишување на фазите на раст на растенијата. Главната цел на истражувањето е користење на комбинација од овие методи за предикција на фазите на раст за целиот период на вегетација. Тригодишните опити 2015/16 – 2017/18 беа лоцирани во Скопскиот Регион, со два генотипа поставени на 30 варијанти и 4 повторувања. Сеидбата е изведена на 1 октомври, со сеидбена норма од 8 $kgha^{-1}$. За регистрирање на фазите на развој се користеше BBCH скалата за маслодајна репка. GDD методот беше одреден преку формула и пресметани корекции за Tmax и Tmin вредности. Никнувањето/'Ртењето (09 BBCH) започна за 7 дена во првата и во третата година – 79 ^{0}C – 65 ^{0}C GDD, а за 8 дена во втората година – 65 ^{0}C GDD. Цветањето (63 BBCH) започна за 202 дена во првата година – 809 ^{0}C GDD, 199 дена во втората година – 649 ^{0}C GDD и 198 дена во третата година – 633 ^{0}C GDD. Полната зрелост (BBCH 97) започна за 254 дена во првата година со акумулирани 1530 ^{0}C GDD, 258 дена во третата година – 1577 ^{0}C GDD и 265 дена со 1542 ^{0}C GDD во втората година. Добиените резултати се во насока на задоволување на потребите на производителите и истражувачите поврзани со производството на маслодајна репка со цел обезбедување на оптимално производство.

Клучни зборови: *маслодајна репка, BBCH, GDD, акумулирана топлина, температури.*