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THE INTERRELATION BETWEEN THE PRODUCTIVITY OF WINTER WHEAT AND WEATHER CONDITIONS IN AUTUMN AND EARLY SPRING PERIODS IN THE NORTHERN STEPPE OF UKRAINE

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Abstract. The main objective of the study was to create scientific and methodological bases for the development, implementation and correction of ecologically adaptive technologies of winter wheat growing in the northern Steppe of Ukraine, depending on the terms of the cessation of vegetation in autumn and its recovery in spring. Winter wheat was sown after black fallow and corn for silage at different dates of sowing from August 25 to October 2, at the intervals of 6-7 days. It has been proved that the terms of the end of autumn vegetation of winter wheat in the northern Steppe of Ukraine influences crops productivity. Higher productivity is formed when growing winter wheat after black fallow and maize for silage in the years when the autumn vegetation ends in the third decade of November. The productivity is respectively 5.67 and 5.58 t/ha. Earlier and later cessation of vegetation causes a decrease in the productivity of winter wheat. The lowest productivity after the two predecessors is formed in the years when the autumn vegetation ends in the first decade of November. For all periods of the autumn vegetation cessation the highest productivity after black fallow is provided by the crops that are sown on September 17. Only in the years with the very early cessation of autumn vegetation winter wheat sown on September 2 is more productive than that sown on October 2. The productivity is respectively 5.17 and 4.68 t/ha. In all years, with the later cessation of autumn vegetation, late crops form higher productivity than early crops sown on September 2. When winter wheat is sown after the maize for silage, in the years with the very early and late cessation of autumn vegetation, the crops sown on October 2 have higher productivity than the crops sown on September 17. The later the vegetation is recovered, the less productivity occurs. In the case of early vegetation recovery (the 3rd decade of February), the productivity of uneven-aged crops is almost the same and ranges from 6.44 to 6.96 t/ha. At the case of late vegetation recovery (early April) the crops sown from 10 to 25 of September, form higher productivity. The average productivity over the years of research was 3.86 – 3.91 t/ha. The productivity of crops sown on September 2 and October 2 is almost the same and is respectively 2.99 and 2.88 t/ha, but it is much higher than the productivity of crops sown on August 25.

Key words: Winter wheat; Cessation of autumn vegetation; Spring vegetation recovery; Productivity.

INTRODUCTION

Weather conditions of autumn and spring vegetation of winter wheat are extremely important for the formation of its harvest (Savranchuk, V.V. 2004; Mostipan, M.I. 2005). The quantity of the harvest as well as its quality depends on the beginning of spring vegetation and further conditions of crop development. V.D. Medynets (1968) was the first who discovered and substantiated a significant influence of the time of spring vegetation recovery on the productivity of winter wheat in Ukraine. He also suggested measures to improve the quality of winter wheat grains and to ensure the level of yield stability, depending on the time of recovery of spring vegetation (Medynets, V.D. 1968). In his further publications, V.D. Medynets (1982) proved that the very nature and characteristics of weather conditions at the beginning of the spring vegetation recovery of winter wheat are crucial in forming the productivity of crops. Brazhenko I.P. (2006) stated that early vegetation is better for plants than the late recovery of vegetation.

The conditions of moisture supply during the spring-summer period of vegetation largely determine the productivity of winter wheat in the northern steppe of Ukraine. It is proved that its productivity after black fallow depends to a great extent on the content of productive moisture in the soil at the time of the recovery of spring vegetation and at the beginning of the plants booting. The share of the effect of the productive moisture reserves in the soil in these periods on the productivity of winter wheat after black fallow is 39.7% and 42.1% for the crops sown on August 25, 55.2% and 24.8% for the crops sown on September 10, and 36.3 and 33.8% - for the crops sown on September 25. Winter wheat sown after maize for silage is more dependent on the reserves of productive moisture in the soil at the time of the recovery of spring vegetation (Mostipan, M.I. 2016; Mostipan, M.I. 2017).

The main objective of the study is to create scientific and methodological bases for the development, implementation and correction of ecologically adaptive technologies of winter wheat growing in the northern steppe of Ukraine depending on the terms of cessation of vegetation in autumn and its recovery in spring.

MATERIALS AND METHODS

Field studies were conducted from 1986 to 2010 at Kirovohrad research station (now Institute of Steppe Agriculture of the National Academy of Agrarian Sciences of Ukraine). Winter wheat was sown after black fallow and maize for silage at different times of sowing from the 25th of August to the 2nd of October at the intervals of 6-7 days. The cultivation technology was developed at Kirovohrad State Agricultural Research Station.

The soils of the experimental site are black medium-humic, heavy-loam soils. The average annual air temperature, according to Kirovohrad weather station, is equal to plus 7.90°C, and the annual amount of precipitation is 474 mm. The major amount of precipitation falls from May to September. The frosty period lasts 164 days.

During the studies, weather conditions were mostly typical for the zone. At the same time, in each of the years, deviations were noted both in terms of the air temperature and the amount of precipitation. The average daily air temperature during the spring-summer period of vegetation of winter wheat during the years of research was 15, 90°C, varying from 13,40°C in 1990 to 18,10°C in 1996. The amount of precipitation during the spring and summer vegetation also varied during the research. On average, over the years of research, precipitation equalled 182 mm from the time of recovery of spring vegetation to solid ripeness of winter wheat. However, in 1996, during this period, only 61 mm of precipitation fell, which is almost three times less than the average for the years of research and 5 times less than the largest amount of precipitation fallen during the years of research in 1997 (318 mm).

RESULTS AND DISCUSSIONS

The obtained results of the research show that the terms of cessation of autumn vegetation influence the formation of winter wheat crop. The later the vegetation of plants of winter wheat ceases, the higher is the plant density. Consequently, the density of the stems increases. Extension of autumn vegetation also affects the phytosanitary state of crops. During the period of research the cessation of autumn vegetation of winter wheat occurred in a fairly wide range of calendar dates, from October 20th (1998) to December 6th (1996). Therefore, for the conditions of the northern steppe of Ukraine it is suggested to distinguish very early cessation of vegetation of winter wheat (third decade of October), early cessation (first decade of November), middle cessation (second decade of November), late cessation (third decade of November) and very late cessation (first decade of December). During the observation period, very early cessation of autumn vegetation was observed for 5 years (25%), early and middle cessation for 7 years (28%), late and very late cessation for 3 years (12%).

The influence of cessation of autumn vegetation of winter wheat on its productivity is complex and can be modified by such agronomic techniques as predecessors and time of sowing. According to the results of studies, the highest productivity of winter wheat (after the two predecessors) was formed in the years with late cessation of autumn vegetation of plants in the third decade of November. Over the years of research, the average productivity of winter wheat after black fallow was 5.67 t/ha and 5.58 t/ha after maize for silage (Fig. 1). In the years with an average cessation of autumn vegetation, the productivity of winter wheat decreased. But a more significant decline was noted after maize for silage. The productivity level after this predecessor decreased from 5.58 to 3.47 t/ha, while after black fallow the productivity was reduced by only 0.34 t/ha.

The results of the research suggest that in the years when autumn vegetation ceases, by the end of the second decade of November, the productivity of winter wheat after black fallow is higher than after maize for silage. So, in the years after vegetation ceased in the first decade of November, the productivity of winter wheat was respectively 4.2 and 3.78 t/ha. In the years when the end of autumn vegetation occurred later, that is, in the third decade of November or the first decade of December, the productivity

of winter wheat after different predecessors was almost the same. On average, over the years of studies with the cessation of vegetation in the first decade of December, the productivity of winter wheat after black fallow was 4.11 tons/ha, and after maize for silage - 4.18 tons/ha.

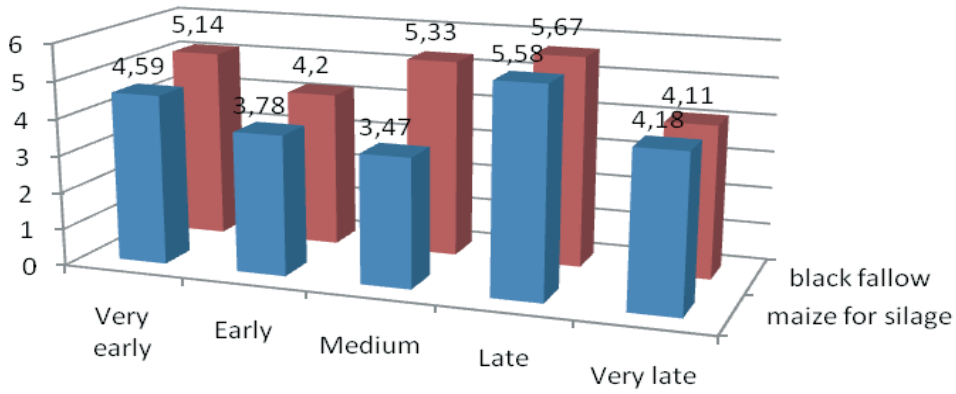

Figure 1. *Productivity of winter wheat depending on the time of cessation of autumn vegetation, t/ha* (1987 - 2010)

It is well known that the sowing time has the greatest impact on the bushiness of plants and the density of winter wheat at the time of autumn vegetation cessation, which in turn determines the potential for productivity [6]. Our research shows that mixed-aged winter wheat has a different reaction to the time of autumn vegetation cessation. In the years of very early cessation of autumn vegetation, the productivity of winter wheat after maize for silage naturally diminished when the sowing time was shifted from September 2nd (4.85 t/ha) to October 2nd (4.16 t/ha). After black fallow, the productivity of winter wheat is higher than after maize. The highest productivity is formed at the sowing date of September 17h and it is 5.58 t/ha. The crops sown on September 2nd are less productive but exceed the crops sown on October 2nd. The productivity of crops sown on September 2nd averages to 5.17 t/ha, and the crops sown on October 2nd equal to 4.68 t/ha (Table 1).

In the years when the autumn vegetation ceases in the third decade of November, the productivity of winter wheat, sown at all times, is higher in compared to the productivity of winter wheat after maize for silage. After both predecessors, the highest productivity is formed at the sowing date of September 17th (5.74 tons/ha) on black fallow and 3.71 tons/ha after maize for silage. It should be noted when winter wheat is sown on black fallow on October 2nd, its productivity is higher compared to the sowing time of September 2nd; whereas after the maize for silage there is a directly opposite dependence. The crops that were sown on September 2nd form higher productivity than the crops sown on October 2nd. Their productivity is respectively 3.44 t/ha and 3.27 t/ha.

Table 1. *Influence of time of cessation of autumn vegetation on productivity of winter wheat, t/ha (1987-2010)*

Vegetation cessation	Black fallow			Maize for silage		
	2.09	17.09	2.10	2.09	17.09	2.10
Third decade of October	5,17	5,58	4,68	4,85	4,77	4,16
First decade of November	3,89	4,61	4,09	3,57	3,90	3,86
Second decade of November	4,89	5,74	5,36	3,44	3,71	3,27
Third decade of November	5,33	5,85	5,82	5,76	5,77	5,20
First decade of December	3,53	4,56	4,25	3,58	4,45	4,50

At late cessation of autumn vegetation in the third decade of November, the highest and almost identical productivity of winter wheat is formed after both predecessors. Under such conditions, the

influence of sowing time on the productivity level is the least noticeable. On average, over the years of research, the productivity of winter wheat after black fallow at different times of sowing varied within the limits of 5.33-5.85 t/ha, and after maize for silage - 5.20-5.77 t/ha. During this period of the autumn vegetation cessation, the productivity of winter wheat after maize for silage sown on September 2nd is higher than that of black fallow and is respectively 5.76 and 5.33 t/ha.

The excessive period of autumn vegetation, which is characteristic in the years with cessation of vegetation of plants in the first decade of December, leads to the reduction of productivity of all uneven-aged crops of winter wheat compared with the years when the vegetation ceased in the third decade of November. After both predecessors, the productivity of crops sown on October 2nd is much higher than of that sown on September 2nd. After black fallow it is 4.25 t/ha, and after maize for silage - 4.5 t/ha against 3.53 t/ha and 3.58 t/ha respectively.

The weather conditions of spring period of winter wheat vegetation are extremely important for the formation of its harvest. The quantity of the harvest as well as its quality depends on the beginning of spring vegetation of plants including the conditions of temperature and humidification for their development. The years of research were characterized by different terms of recovery of spring vegetation of winter wheat. The earliest (February 22nd) was observed in 1990, and the latest (April 4th) in 2003.

The analysis of winter wheat productivity shows that the later is the recovery of spring vegetation, the less is the productivity of winter wheat. At the early recovery of spring vegetation in the third decade of February, the productivity is twice as high as compared with the late recovery in the first decade of April. On average, over the years of research, these indicators were respectively 6.74 and 3.28 t/ha (Fig. 2).

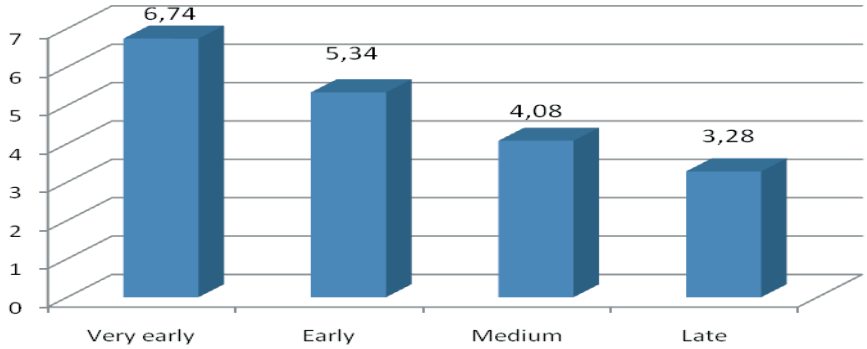

Figure 2. *The influence of the recovery time of vegetation on productivity of winter wheat after black fallow (1986 - 2005)*

The influence of the recovery time of spring vegetation on the productivity of winter wheat depends to a large extent on the sowing time. When the vegetation is recovered in the third decade of February, the productivity of winter wheat is almost independent of the timing of sowing and varies in the range from 6.44 to 6.96 t/ha. Under such conditions, late sowing of crops can compensate the shortage of harvest, which is caused by insufficient bushing of plants during the autumn period of vegetation. In the late sowing time, during early recovery of spring vegetation, there is intensive bushing of plants. At the beginning of booting the crop density increases sharply. The crops of early and very early sowing periods (September 2nd and August 25th), can fully realize their potential (Table 2).

Table 2. *Influence of the recovery time of spring vegetation on productivity of mixed-aged wheat crops, t/ha (1986-2005)*

Recovery tine of spring vegetation	Sowing time					
	25.VIII	02. IX	10. IX	17. IX	25. IX	02. X
Very early (third decade of February)	6,72	6,96	6,77	6,81	6,76	6,44
Early (first decade of March)	4,40	4,73	5,55	6,02	5,90	5,41
Medium (third decade of March)	3,49	3,97	4,43	4,48	4,41	3,73
Late (first decade of April)	2,23	2,92	3,91	3,91	3,86	2,88

The obtained results allow us to assert that the later the recovery of spring vegetation of winter wheat

is, the more clearly the effect of the time of sowing is manifested. Thus, at early recovery of vegetation, the productivity of winter wheat which was sown during the period from September 10th to October 2nd, remains high and ranges from 5.41 to 6.02 t/ha. The decrease of productivity is observed only with the crops sown on August 25th and September 2nd. At late recovery of vegetation, the highest productivity is provided by the crops sown during the period from 10 to 25 September, and their productivity is 3.86 - 3.91 t/ha. But with such a recovery of vegetation, the productivity is sharply reduced both with early and late sowing dates. In terms of sowing on August 25th and September 2nd, the productivity dropped to 2.23-2.92 t/ha, while late sowing on October 2nd dropped to 2.88 t/ha.

Late recovery of vegetation causes a decrease in the productivity of winter wheat, regardless of the sowing time, but it is especially dangerous for the early crops sown on August 25th and late crops sown on October 2nd. The productivity of early crops for such periods of recovery of spring vegetation decreases more than three times, and the latter - by 2.2 times, as compared with the recovery of vegetation in the third decade of February. The productivity of crops sown on August 25th decreases from 6.72 to 2.23 t/ha. The productivity of crops sown on October 2nd decreases from 6.64 to 2.88 t/ha. In the late recovery of vegetation, there is a high probability of the complete death of such crops in the early spring, or their significant density decrease.

Winter wheat crops vividly reveal their on-goings during the early recovery of spring vegetation in the first decade of March. The highest productivity is formed at sowing time of September 17th and 25th and is respectively 6.02 and 5.90 t/ha. This period of vegetation recovery is the shortest for winter wheat sowing. At the same time, the crops sown on October 2nd are more productive than the crops sown on August 25th and even September 2nd. The productivity of crops sown on October 2nd amounted to 5.41 t/ha, while crops sown on September 2nd equalled 4.73 t/ha. At the later recovery of vegetation, the crops sown on October 2nd have less productivity than the crops sown on September 2nd.

The weather conditions of the northern steppe of Ukraine are quite variable by the parameters of the temperature. Therefore, during one year of life of winter wheat plants there may be various correlations between the terms of cessation of vegetation in autumn and its recovery in spring. This determines the length of the quiescence of the winter wheat plants. The results of the research indicate that wheat productivity decreases in years with later recovery of spring vegetation for each of the possible periods of autumn vegetation cessation (Table 3). Such a pattern can be traced after the two studied predecessors.

Table 3. *Productivity of winter wheat, depending on the cessation of vegetation in autumn and recovery of vegetation of plants in spring, t/ha (1986 - 2010)*

Cessation of vegetation	Recovery of vegetation	Predecessor	
		Black fallow	Maize for silage
Very early	medium	5,68	4,10
	Late	5,15	3,82
Early	very early	6,33	5,65
	Early	6,55	7,11
	medium	4,29	3,65
	Late	1,66	0,56
Medium	Early	5,37	3,88
	Late	4,97	3,70
Late	medium	5,65	5,66
Very late	medium	4,40	4,41
	Late	3,38	2,78

From the data in Table 3 it can be seen that on the background of a very early cessation of autumn vegetation, the productivity of winter wheat after black fallow in the years with medium recovery of spring vegetation was 5.68 t/ha, and in the years of its late recovery, reduced to 5.15 t/ha. When winter wheat was sown after a non-fallow predecessor, winter wheat productivity was 4.1 and 3.82 t/ha respectively.

It was noted above that the terms of cessation of autumn vegetation of winter wheat and its recovery in spring have a significant impact on the productivity of winter wheat. It has been established that the highest productivity of winter wheat, irrespective of its predecessors, is formed in the years with the early cessation of autumn vegetation, that is, in the first decade of November and its recovery - in the first decade of March. At the same time, it should be highlighted that only for such a correlation of the terms of cessation

of vegetation in autumn and its recovery in spring, the crops of winter wheat after non-fallow predecessor provide higher productivity than the crops after black fallow. It is respectively 7.11 and 6.55 t/ha.

The productivity of winter wheat is almost independent of its predecessors at a very late cessation of autumn vegetation in December in the years with average terms of its recovery in spring. On average, after black fallow, the productivity of winter wheat in these years is 4.40 t/ha, and after maize for silage is 4.41 t/ha.

The time of sowing has a very specific influence on the productivity of winter wheat after various predecessors, depending on the corelatio of cessation dates of autumn vegetation and its recovery in spring. In the years with a very early cessation of autumn vegetation, at medium and late terms of recovery of spring vegetation, the highest productivity after black fallow is provided by the crops sown on September 17th and it is respectively 5.87 and 5.38 t/ha. Moreover, the early sowing on September 2nd allows forming higher productivity of winter wheat than late sowing on October 2nd. After non-fallow predecessor with a very early cessation of autumn vegetation in the years with the medium recovery of spring vegetation, the productivity of winter wheat decreases from 4.25 t/ha to 3.59 t/ha when sown from September 2nd to October 2nd. And in the years with late recovery of spring vegetation for the same term of cessation of autumn vegetation, the highest productivity is achieved at the sowing on September 17th, but early crops are more productive than late crops (Table 4).

The time of sowing has a great influence on the productivity of winter wheat. But in the years with early cessation of autumn vegetation and very early and medium recovery in spring, the sowing time has no influence. At different periods of sowing, the productivity of winter wheat is almost the same. It is characterised for crops after black fallow as well as after non-fallow predecessor. For example, in the years with early cessation of autumn vegetation and very early recovery in spring, the productivity of mix-aged winter wheat after black fallow varies from 6.46 to 6.26 t/ha. The lowest productivity of winter wheat is formed at the late recovery of spring vegetation with its early cessation in autumn. In such years, early crops on September 2nd can die, and the highest productivity is achieved at the sowing time on September 17th. It is 3,04 t/ha after black fallow, and 1,12 t/ha after maize for silage. Late sowing on October 2nd in these years causes a sharp decline of productivity to 1.16 t/ha after black fallow, and to 0.24 t/ha after non-fallow predecessor.

Table 4. *Productivity of mix-aged crops of winter wheat, depending on cessation of vegetation in autumn and its recovery in spring, t/ha (1986 - 2010)*

Cessation of vegetation	Recovery of vegetation	Black fallow			Maize for silage		
		2.09	17.09	2.10	2.09	17.09	2.10
Very early	medium	5,33	5,87	4,34	4,25	4,0,7	3,5,9
	late	5,03	5,38	4,58	3,83	4,1,3	3,5,3
Early	very early	6,26	6,46	6,34	3,47	5,7,5	5,8,6
	early	7,16	6,33	6,18	7,24	6,7,7	7,0,2
	medium	3,62	3,85	3,61	3,62	3,8,5	3,6,1
	late	0	3,04	1,16	0	1,1,2	0,2,4
Medium	early	2,89	3,57	2,96	2,8,9	3,5,7	2,9,6
	late	4,79	5,69	4,92	3,4,5	4,0,3	3,8,4
Late	medium	5,33	5,85	5,85	5,7,6	5,7,7	3,4,6
Very late	medium	4,33	5,03	4,97	3,8,4	4,3,9	4,5,1
	late	2,62	4,43	3,76	1,6,1	4,0,8	3,4,4

The influence of sowing time on the productivity of winter wheat in the years with medium and very late autumn vegetation is quite different from that in years with very early or early cessation. The highest productivity of winter wheat after both predecessors is provided by the crops sown on September 17th with such terms of cessation of autumn vegetation, irrespective of the terms of recovery of spring vegetation. Another characteristic feature is that in these years, late crops of winter wheat sown on October 2nd after both predecessors have higher productivity than early crops sown on September 2nd.

CONCLUSIONS

Therefore, on the basis of the above material, the following conclusions can be drawn:

- the terms of cessation of autumn vegetation of winter wheat affect its productivity. When growing winter wheat after black fallow and maize for silage, higher productivity is formed in the years when

autumn vegetation ceases in the third decade of November. The productivity is respectively 5.67 and 5.58 t/ha. Early and late cessation of vegetation causes a decrease in productivity of winter wheat. The lowest productivity after the two predecessors is formed in the years when autumn vegetation ceases in the first decade of November;

- mix-aged winter wheat crops have a different reaction to the terms of cessation of autumn vegetation. For all periods of cessation of autumn vegetation, the highest productivity after black fallow is provided by the crops sown on September 17th. Only in the years with early cessation of autumn vegetation, winter wheat crops sown on September 2nd are more productive than late crops sown on October 2nd. Their productivity is respectively 5.17 and 4.68 t/ha. During all years, with later cessation of autumn vegetation, late crops form higher productivity than early crops sown on September 2nd. When winter wheat is grown after maize for silage, the crops sown on October 2nd have higher productivity than the crops sown on September 17th in the years with very early and late cessation of autumn vegetation;

- the productivity of winter wheat in the northern steppe of Ukraine is determined by the time of the recovery of spring vegetation. The later the vegetation is restored, the less productivity it has. In early recovery of vegetation (third decade of February), the productivity of mix-aged crops is almost the same and ranges from 6.44 to 6.96 t/ha. At late recovery of vegetation (early April) higher productivity is formed by the crops sown from 10th to 25th of September. Their average productivity over the years of research was 3.86 - 3.91 t/ha. During this period of recovery of spring vegetation, the productivity of crops sown on September 2nd and October 2nd is almost the same and is respectively 2.99 and 2.88 t/ha, but much higher than the productivity of crops sown on August 25th;

- the productivity of winter wheat in the northern steppe of Ukraine is determined by the correlation of cessation dates of the vegetation in autumn. The highest productivity after black fallow and maize for silage is formed in the years with early cessation of vegetation in autumn in the first decade of November and its recovery in spring in the first decade of March and is respectively 6.55 and 7.11 t/ha. At any term of cessation of autumn vegetation, the later recovery of vegetation in spring forms less productivity of winter wheat irrespective of predecessors.

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