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Rational Way of Forming Stubble Coulisses under North Kazakhstan Conditions

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Abstract. The main limiting factor for increasing yields in the arid steppe conditions of Northern Kazakhstan is moisture. Shoots are usually uneven due to the lack of moisture at the initial stage of their growing. The main source of moisture in this period is winter precipitation. Currently, the following methods of winter precipitation moisture accumulation are used in North Kazakhstan: leaving high standing stubble, seeding coulisses on pure fallow fields, herbicide (chemical) fallow field, snow ridging, harvesting of crops with continuous combining; and forming stubble coulisses. The most preferable way of increasing snow moisture accumulation is the formation of stubble coulisses that can be done in two ways. (*Research purpose*) Efficiency evaluation of the ways of forming stubble coulisses. (*Materials and methods*) Agroengineering and technological evaluation is used as a main research method of different ways of forming stubble coulisses, which is followed by the selection of a more preferable way. (*Results and discussion*) It has been found that in snowy winter both ways of forming stubble coulisses – with alternative passes of a direct combining reaper and a stripping reaper and using a direct combining reaper with a stripper adapter – have shown the same results. However, when there is a little snow in winter, the second way provides more intensive snow accumulation. (*Conclusions*) It has been experimentally found that using the direct combining reaper with the stripper adapter decreases labour inputs by 17.8% and total costs by 23.8% as compared to the formation of coulisses by using sequential passes of the direct combining and the stripping reapers. It has been found that the formation of stubble coulisses every 5-9 meters along with in-line para-plowing at a depth of up to 35 cm provides the highest yield increase of in snowy winter as compared to the conventional ways of moisture accumulation.
Keywords: drought, soil moisture, snow accumulation, moisture accumulation, formation of stubble coulisses, header with a stripper adapter, yield.

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Рациональный способ формирования стерневых кулис в Северном Казахстане

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Реферат. Повышению урожайности в условиях засушливой степи Северного Казахстана препятствует отсутствие влаги. Из-за ее недостатка в почве в начальный период вегетации зачастую получают недружные и изреженные всходы. Основной источник влаги в почве в этот период – зимние осадки. Для их накопления хозяйства Северного Казахстана применяют различные способы: оставление высокой стерни; посев кулис на чистых парах; гербицидный пар; механическое снегозадержание; очес сельскохозяйственных культур в уборочный период, формирование стерневых кулис. Предпочтение отдают формированию стерневых кулис двумя способами. (*Цель исследования*) Оценить эффективность способов формирования стерневых кулис. (*Материалы и методы*) Применяли агротехническую и эксплуатационно-технологическую оценку разных способов формирования стерневых кулис с последующим выбором наиболее предпочтительного варианта. (*Результаты и обсуждение*) Установили, что в снежные зимы способы формирования стерневых кулис чередующими проходами хедера и очесывающей жатки, и применением хедера с очесывающим адаптером показали равнозначные результаты. В малоснежные зимы второй ва-

риант обеспечил наибольшее накопление снега. (*Выводы*) Подтвердили экспериментально, что применение хедера с очесывающим адаптером снижает затраты труда на 17,8 процента, а совокупные затраты – на 23,8 процента по сравнению со способом формирования стерневых кулис сочетанием проходов хедера и очесывающей жатки. Установили, что формирование стерневых кулис с межкулисным расстоянием 5-9 метров в сочетании со щелеванием на глубину до 35 сантиметров обеспечивает наибольшую прибавку урожая в снежные зимы по сравнению с известными способами накопления влаги.

Ключевые слова: засуха, почвенная влага, снегозадержание, влагонакопление, формирование стерневых кулис, хедер с очесывающим адаптером, урожайность.

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The main limiting factor in increasing yields in the arid steppe of northern Kazakhstan is moisture. During the year, the region receives an average of 190-360 mm of precipitation, of which about 60% accounts for the growing season. Drought usually repeats every three years out of ten. Crops are sown in the second half of May. In June, there is an intensive development of vegetative and setting up of generative organs of cultivated plants. However, May and June, the driest months of the growing season, are accompanied by strong hotwinds that dry the soil. Due to the lack of soil moisture and intense solar radiation during this period, farmers often receive uneven and thinned shoots. The lack of moisture results in low stemmed crops and low yields. The average annual indicator of grain yield is 12 centners per hectare with a variation from 3-5 centners per hectare in dry years to 17-20 centners per hectare in wet years. The analysis of climatic conditions revealed that the main source of the soil moisture at the beginning of the growing season is the moisture of winter precipitation. Snow contributes up to 40% of the annual soil moisture reserves. These reserves will be sufficient enough for good shoots and ensure the needs of plants in moisture in the first half of the growing season until the July precipitation falls. Thus, due to the winter precipitation, the basis of the future harvest is laid. For the accumulation of winter precipitation, it is recommended to apply various methods: leaving high standing stubble, seeding coulisses on pure fallow fields, herbicide (chemical) fallow field, snow ridging, harvesting of crops with continuous combining [1-10]. Studies carried out in various conditions indicate that the most preferable way of increasing snow moisture accumulation is the formation of stubble coulisses. [5, 6, 8-10]. This method provides the greatest accumulation of moisture and does not require additional costs for the implementation of agricultural practices. Stubble coulisses can be formed in two ways: by alternating passes of a header and a stripping reaper, as well as the use of a header with a stripper adapter installed in its center [6].

The research purpose is to evaluate the effectiveness of methods for forming stubble coulisses.

Materials and methods. Under production conditions, the author carried out experimental studies and observations of the compared methods of forming stubble coulisses and made their agroengineering and technological assessment followed by the choice of the most preferable option.

Water reserves in the snow between the coulisses was calculated by the formula:

$$Z_m = 10\, h_m \rho_m, \quad (1)$$

where Z_m– water reserves in the snow between the coulisses, mm;

h_m – the average depth of snow between the coulisses, cm;

ρ_m – the average density of snow between the coulisses, g/cm^3.

Water reserves in the coulisse snow was calculated by the formula:

$$Z_k = 10\, h_k \rho_k, \quad (2)$$

where Z_k – water reserves in the coulisse snow, mm;

h_k – the average depth of snow in the coulisse, cm;

ρ_k – the average density of snow in the wings, g/cm^3.

The total water reserves in the snow of stubble coulisses taking into account the distance between the coulisses and the coulisse width, were calculated using the formula:

$$Z_\Sigma = 10\left(\frac{L}{L+b} h_m \rho_m + \frac{b}{L+b} h_k \rho_k\right), \quad (3)$$

where L – the distance between the coulisses, m;

b – coulisse width, m.

Soil moisture reserves and wheat yield were determined by standard methods.

For forming stubble coulisses with alternating passes of the header and the stripping reaper in the conditions of Northern Kazakhstan, use is made of direct combining headers with an operating width of 7, 9, and 12 m and stripping headers with an operating width of 6 m.

Combine harvesters with direct combining headers usually work at a working speed of 5-8 km/h, and with stripping headers – at a speed of 9-10 km/h. The difference in speeds causes the downtime of combine harvesters with stripping headers. Therefore, the technological process is usually performed as follows: first, 4-5 combines with direct combine harvesters operate a field with an area of about 400 hectares and leave for stripping unmown coulisses 3-5 m wide. After their work is completed, a combine with a stripping header strips the unmown coulisses at a higher speed [6]. The width of the formed stubble coulisses is 3-5 m, and an inter-coulisse width is 7-18 m.

A stripper adapter with an operating width of up to 1.5 m is installed in the center of the header with an operating width of 7 or 9 m (*Fig. 1*). A combine harvester of class 4, 5, or 6 equipped with such headers usually works at speeds of up to 8 km/h when forming stubble coulisses.

Fig. 1. Header with a stripper adapter:
a) on the basis of Essil-760 with a header of 9-m width
b) on the basis of Essil-740 with a header of 7-m width

When using direct combining headers with an operating width of 7-9 m equipped with a stripper adapter, the width between the stubble coulisses is 5.5-7.5 m (*Fig. 2*).

Fig. 2. Stubble coulisses left after the header with a stripper adapter

Results and discussion. In snowy winters, moisture reserves in the background of stubble coulisses with an inter-coulisse distance of 5-14 m were 3.5 times higher than those in the stubble background and 2 times higher in the continuous stripping background. Thus, in snowy winters, both ways of forming stubble coulisses - with alternative passes of a direct combining reaper and a stripping reaper and using a direct combining reaper with a stripper adapter – have shown the same results. However, in the low-snow winter of 2017-2018, with the width between the coulisses over 8 m, the snow moisture reserves sharply decreased. Under these conditions, stubble coulisses with an inter-coulisse distance of 5.5-7.5 m, formed by a header with a stripper adapter installed at its center, ensured the greatest accumulation of snow, 1.5-3.0 times higher as compared with other methods (stubble after direct combining, stubble coulisses with an inter-spacing distance of more than 8 m and continuous stripping).

The use of a header with a stripper adapter reduces labor costs by 17.8% and total costs by 23.8% as compared with the method of forming stubble coulisses using a combination of header passes and a stripping header (*Table 1*).

Stubble coulisses are used to increase snow and moisture accumulation in combination with deep tillage. At the same time, stubble coulisses increase snow accumulation, and deep soil tillage enhances the absorption of moisture into the soil.

Stubble coulisses not only help to accumulate moisture, but also retain it. The use of stubble coulisses in combination with para-plowing (slitting) saves moisture reserves better: its content in the soil is by 12-27% higher as compared with deep tillage and by 33-40% – as compared with the stubble background (*Table 2*).

In spring, during the period of dry hotwinds, there is practically no wind at the soil surface in stubble coulisses, as a peculiar microclimate is ensured, and the desiccation of the soil sharply decreases.

The methods of moisture accumulation in the soil after snowy winters affect the wheat yield (*Table 3*). The formation of stubble coulisses with an inter-coulisse distance of 5-9 m in combination with para-plowing (slitting) to a depth of 35 cm provides the greatest yield increase in snowy winters of northern Kazakhstan as compared to the conventional methods of moisture accumulation.

The results obtained indicate the preference of stubble coulisses over full stripping and stubble background. This contradicts the ideas of K.J. Kirkland and C.H. Keys (1981) that the maximum accumulated moisture is observed in standing stubble [7].

However, these results are consistent with the statements of H. Steppuhn, M. Stumborg, G. Lafond and B. McConkey (2009), J.W. Pomeroy, and D.M. Gray (1995) on the advantage of stubble coulisses with an inter- coulisse distance of 10 m over other methods of snow accumulation [9, 10]. However, in contrast to these studies, our results allow to specify the exact value of the inter-coulisse distance in snowy or little-snow winters.

Conclusions

1. It has been found that in the conditions of Northern

Table 1

TECHNICAL AND ECONOMIC CHARACTERISTICS OF DIFFERENT WAYS OF FORMING STUBBLE COULISSES

Characteristics	Ways		Index indicator, %
	Sequential passes	Using header with stripper adapter	
Efficiency per 1 h of operating time/ha	3.6; 2.0	3.6	– 17.8
Specific fuel consumption, kg/ha	4.8 (4.7; 5.0)	4.8	0
Labour costs, man-h/ha	0.33	0.28	17.8
Total costs, tg/ha (rub/ha)	18054 (3224)	13750 (2455)	23.8

Table 2

MOISTURE CONTENT DEPENDING ON FIELD SURFACE

Variants of tests	Soil moisture content within 1 m soil layer, %	
	during soil moisture conservation	before sowing
In-line para-plowing (slitting) at a depth of 35 cm on stubble coulisses arranged every 5-9 m	100	88
In-line para-plowing (slitting) at a depth of 35 cm on stubble coulisses arranged every 14-18 m	92	81
In-line para-plowing (slitting) at a depth of 35 cm on stubble field	80	69
Subsurface tillage at a depth of 30 cm on stubble field	73	61
Untreated stubble field (check plot)	58	68

Table 3

INFLUENCE OF DIFFERENT WAYS OF SOIL MOISTURE ACCUMULATION ON YIELD LEVEL

Ways of moisture accumulation	Average yield, t/ha	Increase in check plot, t/ha
Stubble field (check plot)	1.2	–
1,5 m stubble coulisses every 5-9 m + in-line para-plowing (slitting) at a depth of 35 cm	1.7	0.5
3-4 m stubble coulisses every 14-18 m + in-line para-plowing (slitting) at a depth of 35 cm	1.6	0.4
In-line para-plowing (slitting) at a depth of 35 cm on stubble field	1.5	0.3
Deep subsurface tillage at a depth of 30 cm on stubble field	1.4	0.2

Kazakhstan, a comparison of the methods of stubble coulisse formation in snowy winters by alternating passes of direct-combine harvesters in combination with a stripping header, a wide-cut direct combine harvester with a stripper adapter installed at its center have shown equivalent results. However, in the little-snow winter of 2017-2018 the stubble backstage formed by the direct combine harvester with a stripper adapter installed in its center provided the greatest accumulation of snow.

2. The results of operational and technological evaluation have shown that the use of a header with a stripper adapter reduces labor costs by 17.8% and total costs by 23.8% as compared with the method of forming stubble coulisses using a header and stripping header combination.

3. It has been established that even in snowy winters, the formation of stubble coulisses with an inter- coulisse distance of 5–9 m in combination with para-plowing (slitting) to a depth of 35 cm provides the greatest yield increase in the conditions of Northern Kazakhstan as compared to the conventional methods of moisture accumulation.

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