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Investigation of Changes of Stinging Nettle's (*Urtica dioica* L.) Crop Density

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Abstract. **Recently all countries are looking for the renewable resources. Stinging nettle (Urtica dioica L.) is a perennial plant owning many valuable properties, including yielding natural fibres. Fiber nettle is a cultivated form of the wild nettle. The aim of the research was to investigate changes of productivity of stinging nettle's crop established at different crop densities. Main criterion discussed in the article is the number of the stems per measuring unit (i.e., crop density). The investigation was carried out at the Upytė Research Station of LRCAF in 2008-2012. The crop of different implantation density was established: 60x60 and 60x100 cm. The results of our investigation show that in the first cropping year stinging nettle produced 25-43 stems per plant. Plants from the crop of 2nd year, 60x60, were grosser, more productive than that of the 1st year crop. Plants of the 1st year crop, 60x100, had more stems per plant than that of 1st year crop, 60x60, but amount of stems per ha1 was higher in the crop of 1st year crop, 60x60. The inundation early in 2010 led to the decrease of plant density of stinging nettle's crop. Crop density in the spring was lower than that in the autumn. The greatest increase of amount of stems per plant was found in the plots of lower implantation density (60 x 100 cm). It could be that the optimal crop density (112-136 plants m-2) was already achieved in the crop of 4th and 5th cropping year, and it will not increase any more in more matured crop in following years. Further investigation would be intrigued**

Keywords **– crop density, number of stems, stinging nettle, *Urtica dioica* L.**

I Introduction

Recently the one of main global tasks to survive for the mankind is looking for the renewable resources. We should look around us to decide what can be used with the highest value instead of losing it worthless.

The kingdom of plants is very rich in their appliance. One of such interesting plants is a stinging nettle (*Urtica diocia* L.) which use is very multipurpose [1].

Fiber nettle is a cultivated form of the wild stinging nettle. German researcher Bredemann used many nettle provenances in over 30 years of breeding (1918-1950), from which the most efficient clones were chosen for further development. His criteria for breeding were: frost-tolerance, good growth (long and not ramified, straight and stable stalks, many leaves and strong tillering) and high fiber content [2]. So developed fibre clones have been first selected in 1959 [3]. By the way of selection fiber content was increased from about 5 % in wild nettle plants to up to 17-18 % of stalk dry matter in the cultivated species [2].

Clone varieties dating back to Bredemann are still maintained at research institutions in Germany. After 40 years the plants Bredemann bred during that period (30 clones) have been started to being cultivated again at the Institute of Applied Botany, Hamburg, FRG between 1992 and 1995 [4].

Recently stinging nettle (*Urtica diocia* L.) is currently the subject of scientific interest and development in the some countries through Europe: Germany, Austria, Italy, Finland, UK, the Netherlands, and of course, in Lithuania. This plant is a promising candidate for sustainable production of natural fibre, particularly in Germany and central Europe [5]. Investigations in those countries showed that the nettle's dry stalks matter can vary from 2.3 to 9.7 t ha^{-1} [6]. The fiber yields (fiber yield = fiber content x dry matter yield) ranged from 335 to 411 kg ha^{-1} in second growing year and from 743 to 1016 kg ha^{-1} in third growing year [2]. When growing clones of high productivity (Austrian or German clones of stinging nettle), the yield between 6-8 t ha^{-1} of dry matter of straw with a raw fibre content of up to 25 % (1.5-2.0 t ha^{-1}) could be produced [7].

Investigation of stinging nettle in Italy in 2006-2007 showed that clones of German origin survived well, produced stalks the height of which was 1.71 m, diameter – 5.2 mm. Stalks dry matter in average was 1542 g m^{-2}, i.e. 15.4 t ha^{-1} [8].

First results of the investigation of stinging nettle in Lithuania also gave promising results [1], [9].

Stinging nettle is a perennial plant, but how long it can be productive needs to be investigated. Some author report that the economic life of stinging nettle cultivation is about 6 years, and productive years range from the second to sixth, with a maximum at the third and fourth year [10]. Some other sources report that 4 years is the economic limit of growing fibre nettle in the same place while by the other authors the period of 10-15 years or even without limit is mentioned [6].

The researchers report that fiber yield of stinging nettle increases with plant density [6].

The aim of our research was to investigate changes of productivity of stinging nettle's crop established at different implantation densities as well as of different crop age (the number of growing (harvesting) years).

II MATERIALS AND METHODS

The investigation was carried out at the Upytė Research Station of the Lithuanian Research Centre for Agriculture and Forest. Research was started in 2008 and in still running.

Soil of growing field for stinging nettle was kept free from weeds by the way of soil cultivation. In the autumn it was fertilised by manure and ploughed. In the spring it was cultivated and prepared for plant transportation.

The establishment of the first variant (crop at density 60 (between the plants in the row) x 60 (inter-row spacing) cm) was done in May of 2008. Plants were irrigated, full care of plants was carried out (dead plants were replaced by alive ones, cultivation of inter-row spaces was carried out manually, observations on plant development and growing were conducted). None of pesticides (mineral fertilisers, herbicides, insecticides, fungicides or dessicants) were used for growing of stinging nettle.

In the autumn of 2008, the first yield of stinging nettle was already harvested and evaluated.

In 2009, the 2nd and 3rd variants were founded – the crop of 60 x 60 and 60x100 cm, respectively. In this way the crop of different implantation density was established: 60 x 60 and 60 x 100 cm. Therefore, in 2009 the biometrical indices of the 2nd year crop (established in 2008) and 1st year crop (established in 2009) as well as of different crop density (60 x 60 and 60 x 100 cm) of first year crop have been investigated. Similar observations were carried out in the following years also.

In 2008 and 2009, in the established crop before harvesting all stems of stinging nettle plants (9 plants at crop density of 60 x 60 cm and 6 plants from the plots where crop density is 60 x 100) in the area of 4 m^2 (2 x 2 m) (in tree replications) were cut (leaving the stubble of 15 cm for sprouting of the plant) for the evaluation. Then the data were re-calculated for 1 m^{-2}, 1 ha^{-1}, for 1 plant.

In 2010, 2011 and 2012 all stems of stinging nettle in the area of 4 m^2 (2 x 2 m) (in tree replications) were cut as the inter-rows already could not be visible because of increased density of the crop. In 2010, some inter-row space still could be noted in the crop at density of 60 x 60 cm.

For statistical data evaluation the statistical software developed in the Lithuanian Institute of Agriculture was used [11].

In 2008 the weather conditions (Tables 1 and 2) were favorable for the naturalization of transferred stinging nettle plants (sufficient amount of precipitation on I and II ten-day periods of May). Later on (III ten-day period of May and I of June) the luck of precipitation occurred, and stinging nettle was irrigated manually. The second part of June was rainy. Meteorological conditions were favorable for growing of stinging nettle. Stinging nettle from 1st year crop was harvested on 3rd of September.

In 2009 the beginning of the vegetation of stinging nettle was observed on the III ten-day period of April. For the establishment of different density crop weather was selected to be rainy and overcast (beginning of May), transferred stinging nettle also was irrigated manually. Later on (on I and II ten-day period of May) the luck of precipitation occurred. June and July had sufficient rainfall for stinging nettle. Plants were thriving well and flowering for a long time. Stinging nettle was harvested on 15th of August.

In 2010, the first green shoots have been found on the 3rd of April, but the weather was still cool. The inundation on the part of stinging nettle's crop was recorded at the end of March, and it has negative influence on the crop, detectable even few years later – the amount of stinging nettle's shoots decreased; the weeds occupied free place. Stinging nettle was harvested on 30th of August.

TABLE 1.

MEAN WEATHER TEMPERATURE AND PRECIPITATION DURING STINGING NETTLE'S GROWING SEASON

UPYTĖ, 2008-2012

Month	Ten-day period	Mean weather temperature, ºC					
		2008	2009	2010	2011	2012	Long-term average
May	I	8.5	12.1	12.6	11.2	12.1	11.0
	II	11.8	15.3	15.6	12.6	12.1	12.6
	III	13.4	17.6	15.1	14.9	15.1	13.5
	Aver./total	11.2	15.0	14.4	12.9	13.1	12.4
June	I	17.0	16.3	18.4	16.5	12.9	14.4
	II	15.0	17.3	15.9	18.7	16.5	15.3
	III	15.4	21.3	17.8	19.6	15.3	16.2
	Aver./total	15.8	18.3	17.4	18.3	14.9	15.3
July	I	16.8	21.9	21.3	22.6	21.1	17.2
	II	17.9	20.5	24.5	22.6	16.0	18.0
	III	17.4	18.5	23.9	21.3	20.1	18.0
	Aver./total	17.4	20.3	23.2	22.2	19.1	17.7

August	I	17.1	17.6	23.9	16.7	18.1	17.2
	II	19.9	17.6	23.3	18.2	16.5	16.1
	III	16.1	15.8	15.3	17.0	15.0	15.0
	Aver./total	17.7	17.0	20.9	17.3	16.5	16.1
September	I	16.9	16.6	12.5	14.1	14.1	-
	II	8.3	14.0	11.3	12.6	13.9	-
	III	10.7	15.0	14.7	13.6	11.7	-
	Aver./total	12.0	15.2	12.8	13.4	13.2	-
October	I	8.1	7.1	12.6	11.0	9.7	-
	II	9.9	2.8	4.5	6.0	8.6	-
	III	7.9	5.4	8.3	5.8	3.5	-
	Aver./total	8.6	5.1	8.5	7.5	7.2	-

TABLE 2.

AMOUNT OF PRECIPITATION DURING STINGING NETTLE'S GROWING SEASON

UPYTĖ, 2008-2012

Month	Ten-day period	Rainfall, mm					
		2008	2009	2010	2011	2012	Long-term average
May	I	16.1	10.0	25.0	1.0	12.5	16.0
	II	12.5	2.1	18.0	19.0	27.0	16.0
	III	0.1	10.5	20.5	7.0	39.0	18.0
	Aver./total	28.7	22.6	63.5	27.0	78.5	50.0
June	I	0.0	57.0	11.0	11.0	36.5	22.0
	II	32.0	21.0	49.5	15.0	13.5	23.0
	III	56.0	7.5	21.0	13.5	41.5	24.0
	Aver./total	88.0	85.5	81.5	39.5	91.5	69.0
July	I	9.5	37.5	28.0	37.0	33.0	25.0
	II	41.0	55.0	17.0	28.0	49.0	25.0
	III	15.5	30.0	72.0	69.5	30.0	26.0
	Aver./total	66.0	122.5	117.0	134.5	112.0	76.0
August	I	47.5	0.0	11.0	29.5	44.0	28.0
	II	44.5	28.5	30.5	36.5	10.5	29.0
	III	21.1	45.0	27.0	29.0	28.0	28.0
	Aver./total	113.1	73.5	68.5	95.0	82.5	85.0
September	I	4.5	17.0	8.0	21.0	14.0	-
	II	5.0	21.0	20.0	28.0	29.0	-
	III	2.0	10.0	27.0	1.0	1.0	-
	Aver./total	11.5	48.0	55.0	50.0	44.5	-
October	I	10.3	38.0	0.0	5.0	31.0	-
	II	44.6	36.0	10.0	11.0	15.0	-
	III	31.5	12.0	18.0	2.0	12.0	-
	Aver./total	86.4	86.0	28.0	18.0	58.0	-

In 2011 already in the middle of March small (0.5 cm) violet shouts of stinging nettle have been noticed after the snow has melted. Nevertheless, meteorological conditions still were not suitable for growing. In the beginning of April, the shouts of stinging nettle were already 3 cm in height; the vegetation started early. Stinging nettle was thriving well; it was harvested on 12th of September.

The spring in 2012 came late. In the beginning of May stinging nettle started to grow. Despite the quite great amount of precipitation, the plants were not very luxury. Stinging nettle was harvested on 4th of September.

III RESULTS AND DISCUSSION

The biometrical indices of stinging nettle's crop in 2008 and 2009 were evaluated only at harvesting time, because in the spring there were only few stems (plants) in measuring unit (9 plants per 4 m^{-2} (i.e., 2.25 stems per 1 m^{-2}) in the plots at crop density 60 x 60 cm, and 6 plants per 4 m^{-2} (i.e., 1.5 stems per 1 m^{-2}) in the plots at crop density 60 x 100 cm).

In 2008, in the crop of the 1st year, crop density 60 x 60 cm, the amount of stems per 1 plant varied from 15 to 79, but the average was close to 43 stems per plant (Table 3). Amount of stems in 1 m^2 was close to 100, i.e., it increased from 2.25 to 96.3 units 1 m^{-2}, or 1 plant produced more than 40 stems.

TABLE 3.

THE BIOMETRICAL INDICES OF THE 1ST YEAR STINGING NETTLE CROP (ESTABLISHED IN 2008), 60 X 60 CM (ABBREVIATION OF THE TREATMENT – 1ST YEAR, 60X60) AT HARVESTING UPYTĖ, 2008

The biometrical indices	Mean
Amount of stems (number 1 m^{-2})	*96.3*
Amount of stems (number per plant)	*42.8*
Amount of stems (number ha^{-1})	963 333

In the last rows of the presented tables we can see what huge amount of stems could be produced in 1 ha.

In 2009 in the crop of the 2nd year, 60x60, plants were grosser than that of the 1st year crop. The amount of stems (number per plant) varied from 12 to 68. The highest significant averaged amount of stems (42.9 units per plant) was found to be in the crop of 2nd year, 60x60 (Table 4). Plants of the 1st year crop, 60x100, had more stems per plant (32.9) than that of 1st year crop, 60x60 (25.4), but the differences between treatments were not significant. Nevertheless, amount of stems (number ha^{-1}) was significantly higher in the crop of 2nd year, 60x60, and significantly lower in the crop of 1st year, 60x100. In 2009 the stems of stinging nettle were less branched than that in 2008.

In 2009, in the crop of the 2nd year, 60x60 the number of stems per plant was very similar to that in 2008, i.e., 1 plant in the second year did not produce any more new stems.

In 2009 the amount of stems per plant was lower than that in 2008. In the 1st year crop 1 plant produced close to 33 stems at lower density (60 x 100) (while in 2008 it was close to 43 stems per plant) and close to 25 stems at higher density (60 x60). Crop density in the nettle trials in Italy was found to be much higher – it was close to 132 stems m^{-2} of 2nd cultivation year (implantation density was 50x75 cm) [12].

TABLE 4.

THE BIOMETRICAL INDICES OF STINGING NETTLE CROP AT HARVESTING UPYTĖ, 2009

The biometrical indices	2dn year, 60x60**	1st year, 60x60**	1st year, 60x100**	Mean
Amount of stems (number 1 m^{-2})	96.6*	57.2	44.8*	66.17
(LSD_{05} 17.23)				
Amount of stems (number per plant)	42.9	25.4	32.9	33.7
(LSD_{05} 9.19)				
Amount of stems (number ha^{-1})	965 833*	571 667	493 333*	676 944
(LSD_{05} 179 361)				

* – significant at 0.05 probability level;

** – the 2dn year stinging nettle crop (established in 2008), 60 x 60 cm (abbreviation of the treatment – 2dn year, 60x60); the 1st year crop (established in 2009), 60 x 60 cm (abbreviation of the treatment – 1st year, 60x60); the 1st year crop (established in 2009), 60 x 100 cm (abbreviation of the treatment – 1st year, 60x100).

Since 2010 we started calculating the crop density also in spring (in May). As some part of the stinging nettle suffered from the inundation early in 2010, the results show decrease of crop density when compare to that in the autumn, 2009 (Tables 5 and 4). The differences between variants in crop density and amount of stems per plant were significant.

TABLE 5.

THE BIOMETRICAL INDICES OF STINGING NETTLE CROP IN SPRING UPYTĖ, 2010

The biometrical indices	3rd year, 60x60**	2dn year, 60x60**	2nd year, 60x100**	Mean
Amount of stems (number 1 m^{-2})	57.9	45.4	23.7	42.33
(LSD_{05} 4.47)				
Amount of stems (number per plant)	25.7*	20.2	15.8*	20.57
(LSD_{05} 2.12)				
Amount of stems (number ha^{-1})	579 167*	454 167	236 667*	423 333
(LSD_{05} 44 744.9)				

* – significant at 0.05 probability level;

** – the 3rd year stinging nettle crop (established in 2008), 60 x 60 cm (abbreviation of the treatment – 3rd year, 60x60); the 2nd year crop (established in 2009), 60 x 60 cm (abbreviation of the treatment – 2nd year, 60x60); the 2nd year crop (established in 2009), 60 x 100 cm (abbreviation of the treatment – 2nd year, 60x100).

During growing season in 2010, amount of stems per plant have increased, but the differences between variants were not significant (Table 6). The greatest increase was found in the plots of lower implantation density (60 x 100 cm) – from 16 to 37 stems per plant per growing season. In the plots with implantation density 60 x 60 cm, increase of stem amount per plant was rather similar –

13.9-16.0 stems per plant per growing season, and was not depending on crop maturity (3rd or 2dn cropping year). In the trials of Hartl and Vogl, in the third cultivation year the amount of stems per plot (implantation density was 60 x 100 cm) was doubled when compared with those from the second cultivation year [2].

TABLE 6.

THE BIOMETRICAL INDICES OF STINGING NETTLE CROP AT HARVESTING UPYTĖ, 2010

The biometrical indices	3rd year, 60x60**	2dn year, 60x60**	2nd year, 60x100**	Mean
Amount of stems (number 1 m^{-2})	89.1	81.5	55.4	75.33
(LSD_{05} 27.90)				
Amount of stems (number per plant) (LSD_{05} 13.65)	39.6	36.2	36.9	37.59
Amount of stems (number ha^{-1})	890 833	815 000	554 167	753 333
(LSD_{05} 279 026.1)				

** – the 3rd year stinging nettle crop (established in 2008), 60 x 60 cm (abbreviation of the treatment – 3rd year, 60x60); the 2nd year crop (established in 2009), 60 x 60 cm (abbreviation of the treatment – 2nd year, 60x60); the 2nd year crop (established in 2009), 60 x 100 cm (abbreviation of the treatment – 2nd year, 60x100).

In the spring, 2011, crop density was again lower than that in the autumn 2010, but rather similar to that in the spring, 2010. In the spring, 2011, the amount of stems per plant was rather similar in all treatments (20.5-25.7), nevertheless, the amount of stems per 1 m^2 was higher in mature crop (4th year, 60x60) than that in younger crop (3rd year, 60x60), and higher in the plots of the crop of higher implantation density (60 x 60 cm) than that in the plots of lower implantation density (60 x 100 cm) (Table 7). The differences between treatments were not significant.

TABLE 7.

THE BIOMETRICAL INDICES OF STINGING NETTLE CROP IN SPRING UPYTĖ, 2011

THE BIOMETRICAL INDICES	4TH YEAR, 60x60**	3RD YEAR, 60x60**	3RD YEAR, 60x100**	MEAN
AMOUNT OF STEMS (NUMBER 1 M^{-2})	56.3	46.1	38.6	46.97
(LSD_{05} 11.40)				
AMOUNT OF STEMS (NUMBER PER PLANT) (LSD_{05} 5.44)	25.0	20.5	25.7	23.73
AMOUNT OF STEMS (NUMBER HA^{-1})	562 500	460 833	385 833	469 722
(LSD_{05} 114 035.87)				

** – the 4th year stinging nettle crop (established in 2008), 60 x 60 cm (abbreviation of the treatment – 4th year, 60x60); the 3rd year crop (established in 2009), 60 x 60 cm (abbreviation of the treatment – 3rd year, 60x60); the 3rd year crop (established in 2009), 60 x 100 cm (abbreviation of the treatment – 3rd year, 60x100).

Growing season in 2011 was favourable for stinging nettle – crop density increased more than twice. The differences between variants were not significant, but crop density was over 100 stems per 1m^2 (Table 8). When compared older and younger crop (60 x 60 cm), matured crop showed better results. When compared different implantation density crop (60 x 60 cm and 60 x 100 cm), the lower implantation density crop showed better results. The amount of stems per 1 plant was significantly higher in the plots of lower implantation density crop (60 x 100 cm) – even 82.2 stems per 1 plant.

TABLE 8.

THE BIOMETRICAL INDICES OF STINGING NETTLE CROP AT HARVESTING UPYTĖ, 2011

The biometrical indices	4th year, 60x60**	3rd year, 60x60**	3rd year, 60x100**	Mean
Amount of stems (number 1 m^{-2}) (LSD_{05} 40.12)	121.8	106.7	123.3	117.28
Amount of stems (number per plant) (LSD_{05} 20.06)	54.2	47.4	82.2*	61.26
Amount of stems (number ha^{-1}) (LSD_{05} 401225.20)	1 218 333	1 066 667	1 233 333	1 172 778

* – significant at 0.05 probability level;

** – the 4th year stinging nettle crop (established in 2008), 60 x 60 cm (abbreviation of the treatment – 4th year, 60x60); the 3rd year crop (established in 2009), 60 x 60 cm (abbreviation of the treatment – 3rd year, 60x60); the 3rd year crop (established in 2009), 60 x 100 cm (abbreviation of the treatment – 3rd year, 60x100).

In the spring, 2012, crop density again was lower than that in the autumn, 2011, but it was much more higher than that in the spring 2011 in the plots of different implantation density crop (60 x 60 cm and 60 x 100 cm) (Table 9). The amount of stems per 1 plant in the beginning of vegetation was significantly higher in the plots of lower implantation density crop (60 x100 cm).

TABLE 9.

THE BIOMETRICAL INDICES OF STINGING NETTLE CROP IN SPRING UPYTĖ, 2012

The biometrical indices	5th year, 60x60**	4th year, 60x60**	4th year, 60x100**	Mean
Amount of stems (number 1 m^{-2})	57.9	83.7	90.6	77.39
(LSD_{05} 29.03)				
Amount of stems (number per plant) (LSD_{05} 17.90)	25.7	37.2	60.4*	41.10
Amount of stems (number ha^{-1})	579 167	836 667	905 833	773 889
(LSD_{05} 1 161 281.8)				

* – significant at 0.05 probability level;

** – the 5th year stinging nettle crop (established in 2008), 60 x 60 cm (abbreviation of the treatment – 5th year, 60x60); the 4th year crop (established in 2009), 60 x 60 cm (abbreviation of the treatment – 4th year, 60x60); the 4th year crop (established in 2009), 60 x 100 cm (abbreviation of the treatment – 4th year, 60x100).

Crop density at harvesting in 2012 was rather similar to that in 2011 at harvesting. It could be that the optimal crop density is already achieved, and it will not increase any more in more matured crop in following years. Crop density was approximately the same in more matured and younger crop, 60 x60 cm (112-115 plants m^{-2}), and higher – in the plots of lower implantation density crop (60 x 100 cm) – even 136.4 stems per 1 m^2. Crop density during growing season in 2012 has increased, but not as great as it was in 2011. In 2012 as well as in 2011, the highest amount of stems per 1 plant was significantly higher in the plots of lower implantation density crop (60 x 100 cm) – even 90.9 stems per 1 plant.

TABLE 10.

THE BIOMETRICAL INDICES OF STINGING NETTLE CROP AT HARVESTING UPYTĖ, 2012

The biometrical indices	5th year, 60x60**	4th year, 60x60**	4th year, 60x100**	Mean
Amount of stems (number 1 m^{-2}) (LSD_{05} 54.38)	114.7	112.2	136.4	121.08
Amount of stems (number per plant) (LSD_{05} 29.00)	51.0	49.9	90.9	63.92
Amount of stems (number ha^{-1}) (LSD_{05} 153333.3)	1 146 667	1 121 667	1 364 167	1 210 833

** – the 5th year stinging nettle crop (established in 2008), 60 x 60 cm (abbreviation of the treatment – 5th year, 60x60); the 4th year crop (established in 2009), 60 x 60 cm (abbreviation of the treatment – 4th year, 60x60); the 4th year crop (established in 2009), 60 x 100 cm (abbreviation of the treatment – 4th year, 60x100). (established in 2009), 60 x 100 cm (abbreviation of the treatment – 3rd year, 60x100).

IV CONCLUSION

In the first cropping year stinging nettle produced 25-43 stems per plant.

Plants from the crop of 2nd year, 60x60, were grosser, more productive than that of the 1st year crop.

Plants of the 1st year crop, 60x100, had more stems per plant than that of 1st year crop, 60x60, but amount of stems per ha[1] was higher in the crop of 1st year crop, 60x60.

The inundation early in 2010 led to the decrease of crop density of stinging nettle's crop.

Crop density in the spring was lower than that in the autumn.

The greatest increase of amount of stems per plant was found in the plots of lower implantation density (60 x 100 cm).

It could be that the optimal crop density (112-136 plants m^{-2}) was already achieved in the crop of 4th and 5th cropping year, and it will not increase any more in older crop in following years. Further investigation would be intrigued

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