

## ANALYSIS OF THE PLACEMENT OF LOOSENING AND APPLYING FERTILIZER TINES IN SOIL STRIPS AT DIFFERENT SPACINGS BETWEEN PLANT ROWS

### Summary

The paper presents analysis of aggregates and tillage-sowing cultivators equipped with soil loosening and fertilizer applying tines in the aspect of correlating rows of fertilizer with rows of plants and discusses the resulting differences. Examples of tine placement patterns in adjustable spacing are shown, allowing the aggregate to be adapted to localized fertilization during sowing of various plants.

**Key words:** localized fertilization, tillage, fertilizer application, seed sowing, row spacing

## ANALIZA ROZMIESZCZENIA ZĘBÓW SPULCHNIAJĄCYCH PASOWO GLEBĘ I APLIKUJĄCYCH NAWÓZ PRZY RÓŻNYCH ROZSTAWACH RZĘDÓW ROŚLIN

### Streszczenie

Przeanalizowano agregaty uprawowe i uprawowo-siewne wyposażone w zęby spulchniające pasowo glebę i aplikujące nawóz w aspekcie skorelowania rzędów nawozu z rzędami roślin i omówiono wynikające z tego różnice. Przedstawiono przykładowe schematy rozmieszczenia zębów w regulowanym rozstawie, umożliwiającym przystosowanie agregatu do zlokalizowanego nawożenia podczas siewu różnych roślin.

**Słowa kluczowe:** nawożenie zlokalizowane, uprawa roli, aplikacja nawozu, siew nasion, rozstaw rzędów

### 1. Introduction

Mineral fertilization is an important agronomic factor increasing the yield of arable crops. The way to achieve high yields this is not only the use of high fertilization levels, but also the conditions that increase the use of fertilizers by plants [1]. Fertilization efficiency can be improved, inter alia, by the application of localized fertilization, which consists in soil application of fertilizer in a line correlated with the rows of plants [2]. Placing the fertilizer in the soil, close to the rows of plants not only improves its utilization but also ensures rapid and equal development of all crops and increased competition for weeds. Localized fertilization can be combined with various treatments, such as mechanical weeding, sowing, tillage, but simultaneous soil cultivation, fertilization and sowing is the greatest simplification in the number of field strips [2]. Tillage-sowing cultivators use different methods of simultaneous application of fertilizer, depending primarily on the spacing of rows of plants and on the method of tillage, which can be made to varying depths and cover the entire field surface or only narrow stripes (strip-till).

On market increasing range of offered solutions that allow the application of fertilizers in simplified no-tillage systems, especially the tines, which enable not only the localized application of the fertilizer, but also the localized in row soil loosening [3].

Studies confirm that it is possible, to simultaneously perform strip tillage, fertilization and maize sowing, even in fields with a large amount of crop residue after harvest of the maize for grain [4].

### 2. Localized fertilization in plant cultivation with large row spacing

For large row-spaced plants the standard strip-till cultivation is used, which only prepares the soil in narrow sowing lines. Standard strip-till cultivation usually consists of clearing the sowing strips from the excess of crop residues and

arranging them between rows (Fig. 1) and deep (up to 35 cm) soil loosening and secondary compaction. The characteristics of the aggregates for standard strip-till are the combination of working elements in the cultivation sections and application of fertilizer exactly in the axes of the plant rows. It is apparent from the analysis of aggregates adapted to the standard strip-till (Table 1) that the spacing of the cultivating sections is usually in the range of 45-80 cm, corresponding to the spacing of rows, i.e. maize or beet, although the spacing of 37.5 cm is also used for rape oil seeds.



Fig. 1. Standard strip-till cultivation at large row spacing [7]

Rys. 1. Standardowa uprawa pasowa przy dużym rozstawie rzędów [7]

The large spacing of the cultivating sections and the removal of crop residues before the tines make possible to position the tines in one row without any clog. However, at smaller spacing (37.5 cm), it is necessary to set up working sections in two rows, which reduces the operating resistance and the danger of section block. The depth of fertilizer application may be similar to the depth of soil cultivation or adjustable to this level. It should be noted, that the use of a precision seeder in strip-till also enables the shallow application of fertilizer alongside the rows, as these seeders are mostly equipped with fertilizer applicators.

Table 1. Characteristics of cultivation aggregators and tilling-and-sowing equipments adapted to the localized fertilizer application

Tab. 1. Charakterystyka agregatów uprawowych i uprawowo-siewnych przystosowanych do zlokalizowanej aplikacji nawozu

Manufacturer (Aggregate model)	Fertilizer and seed application	Spacing of rows fertilizer/seeds [cm]
Duro-France (Strip-till integral)	- application of fertilizers to the soil at 15-30 cm deep, - seed sowing with point seeder,	45; 50; 60; 75
Kuhn (Striger)	- application of fertilizer to the soil up to 30 cm deep, - sowing seeds with a point seeder in a separate treatment,	45; 50; 55; 60; 70; 75; 80
Kverneland (Kultistrip)	- application of fertilizer using tines loosening soil up to 30 cm deep, - sowing seeds with a point seeder in a separate treatment,	45-80
Czajkowski (ST)	- application of fertilizer using tines at a depth of 10-35 cm, - seeding with a coulter section, placing seeds in strips 25 cm wide at 37.5 cm spacing or with point seeder at 45 and 75 cm spacing,	37,5 / 37,5 (strips) 45 / 45 75 / 75
Horsch (Focus TD)	- application of fertilizer with tines shallow or deep (up to 35 cm) - seeding with disc coulter,	30 / 15 30 / 30
Vaderstad (Spirit C StripDrill)	- application of fertilizer with tine at two depths (shallow - up to 15 cm, deep - up to 30 cm), - seed sowing with disc coulters,	33,4 / 33,4 33,4 / 16,7
Claydon (Hybrid Drill)	- application of fertilizer with tines to a depth of 10-18 cm, - sowing seeds with coulters in 8, 12 or 18 cm wide belts,	30 / 30 (strips)
Mzuri (Pro-Til 3T)	- application of fertilizers with tines, - seeds are sown using coulters spreading them in rows or strips overlapping with rows of fertilizer or in rows on either side of previously applied fertilizer.	33,3 / 33,3 (rows, double rows or stripes)
McConnel (Seederator)	- application of fertilizer by tines to a depth of 10-30 cm, - seeds are sown by coulters in widths of 6, 15 or 17 cm,	33,3 / 33,3 (strips)
Agro-Masz (Salvis)	application of fertilizer by tines, - seed sowing with disc coulters,	33,3 / 16,7
Farmet (Falcon)	- aplikacja nawozu zębami spulchniającymi glebę na głębokość do 20 cm przy rozstawie 25 i 30 cm lub do 30 cm przy rozstawie 37,5 cm, - application of fertilizers to soil by loosening tines up to 20 cm at a spacing of 25 and 30 cm or 30 cm at a spacing of 37.5 cm, - seed sowing with disc coulters,	25 / 12,5 30 / 15 25 / 25 30 / 30 37,5 / 37,5
Kockerling (Master)	- aplikacja nawozu zębami spulchniającymi glebę na głębokość do 35 cm, - wysiew nasion sekcją z redlicami tarczowymi lub siewnikiem punktowym, - application of fertilizer with loosening tines up to 35 cm deep, - seed sowing with disc coulters or point seeder,	30 / 15 30 / 30 45 / 45 75 / 75

Source: own work / Źródło: opracowanie własne

Standard strip-till can be combined with sowing, but large row spacing also makes possible to use cultivation with sub soil fertilizer application in a separate pre-sowing task. The condition of proper placement of localized fertilization and sowing in separate treatments is to arrange working passages in that way that the rows of seeds are in line with the axes of the previously drilled fertilizer rows.

The width and spacing of the wheels of the tractor cooperating with the seeder should be correlated with the width and spacing of inter-rows so as not to knead the previously loosened seed strips. It is a good idea to use while sowing tractors with narrow twin wheels, which divide the pressures into four inter-rows. Ordering further work rides can be ensured by using a tractor equipped with satellite navigation and increasing its accuracy with a correction signal. The use of GPS and autopilot enables the cultivation of the strip with fixed width of the inter-rows without the need for markers, and the computer saved rides can be mapped during sowing regardless of the visibility of traces of the previously made strip-tillage.

### 3. Fertilization located in the cultivation of cereals and rape

The specificity of aggregates for simultaneous deep tillage, localized fertilization and cereal sowing results primarily from the adaptation to the shorter row spacing than the standard tillage cultivators. Of course, in narrow inter-rows

there is no possibility of separate cultivation with fertilization and sowing. At the maximum row spacing, which according to traditional agrotechnical recommendations for cereals is 15 cm, deep soil loosening in the axis of each row would result in high working resistances, therefore, the increased spacing of the tine corresponding to the second inter-row (Fig. 2) is used in the aggregates adapted for cereal sowing. or wide rows of plants. Only in the case of rape sowing with these aggregates the spacing of rows of plants, as in the standard crop rows, corresponds to the spacing of the tines applying fertilizer (Fig. 2).

Aggregates with tines in scale of 25, 30 and 33.4 cm are equipped with disc coulters that seed cereals in rows of 12.5, 15 and 16.7 cm respectively. On the other hand, in coulters applying fertilizer in rows with a spacing of 33.4 cm and larger, there are used tine coulters which sow seeds in narrow rows (double rows of plants) (Fig. 3) or in wide strips in line with row of fertilizers (Fig. 4). In row sowing, irrespective of the distribution of rows, each row of plants has the same access to the loosened soil and the fertilizer placed on it, while at the strip sowing every row of fertilizer supplies one strip of plants. With unequal distribution of sowing rows (double rows) the fertilizer mid-rows are narrower than those without fertilizers, while in cereal strip sowing the width of the mid-rows between crop strips, depending on the width of the strips (e.g. 12, 18, 25 cm) and the spacing of rows of fertilizer, in range of 12.5 to 18 cm. Of course, rapeseed can

also be used as a strip sowing, but then the narrower width of the strips (i.e. 8 cm) is used, and the width of the rows between the strips is more than 20 cm.

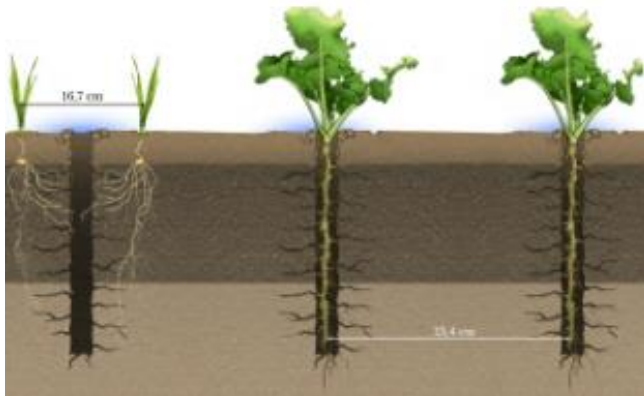


Fig. 2. Localized soil loosening and fertilization at different row spacing according to Vaderstad company [7]  
Rys. 2. Zlokalizowane spulchnienie gleby i nawożenie przy różnych rozstawach rzędów wg firmy Vaderstad [7]

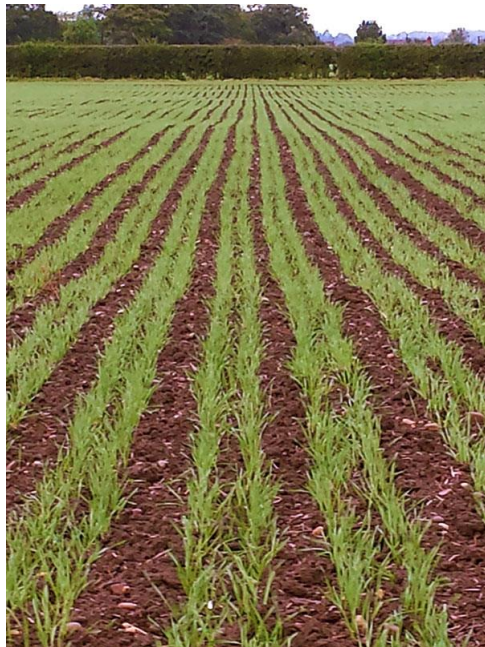


Fig. 3. Double rows of wheat sown on both sides of fertilizer rows [6]  
Rys. 3. Podwójne rzędy pszenicy wysianej po obu stronach rzędów nawozu [6]

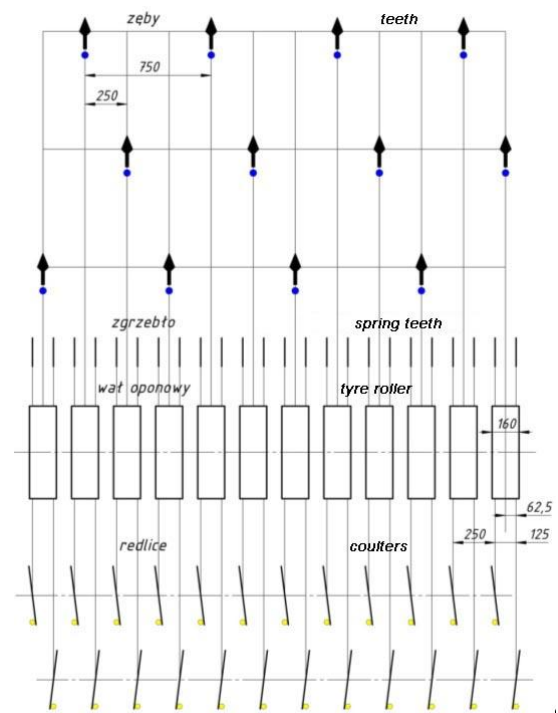


Fig. 4. Wide grain strips sown in the traces of fertilizer application tines [5]  
Rys. 4. Szerokie pasy zboża wysianego w śladach pracy zębów aplikujących nawóz [5]

#### 4. Adjustable spacing of tines

The analysis shows that the cultivation unit with options of loosening soil in rows and fertilizer application in front of seed sowing coulters can be adapted to different row spacing and soil conditions by changing the number and spacing of tines and the exchangeable tools can be mounted on a suitably adapted frame.

By arranging the tines in three rows, the soil can be loosened and the fertilizer applied in lines of 25 cm, typical of rapeseed sown by regular row seeders. On the other hand, cereal seeds can be sown in 12.5 cm lines (Fig. 5) aligned with respect to the fertilizer, which is most commonly used in traditional cereal crops, and very rarely in the currently offered strip-till combined with localized fertilization. The distance between the rows of cereal seeds from the fertilizer application traces is 6.25 cm and even for shallow applications, the fertilizer portion is safe for germinating seeds, but provides quick access to the beam root system for fertilizer. The small width of the inter-rows is also beneficial due to the quick closing of the crop and increased competition for weeds.



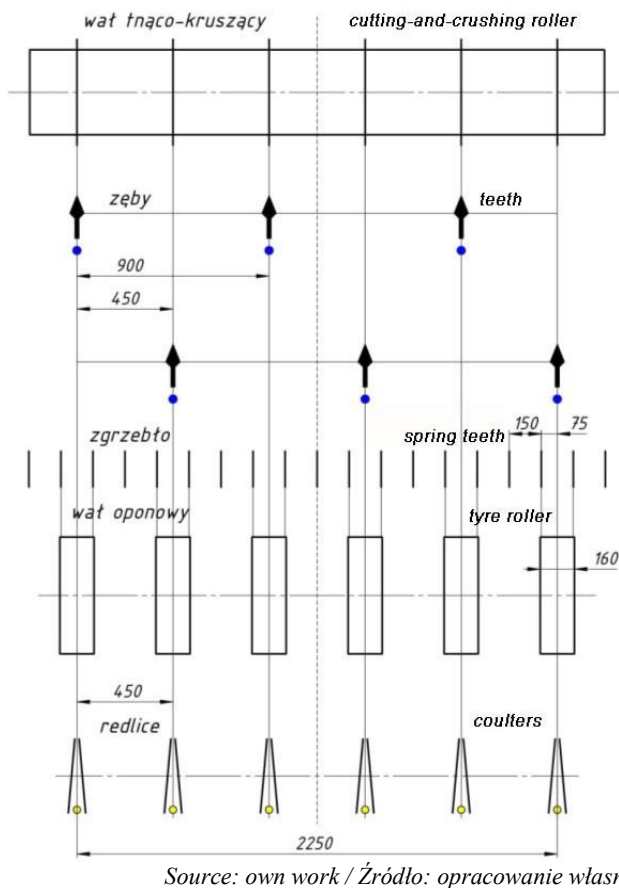
Source: own work / Źródło: opracowanie własne

Fig. 5. Schematic diagram of the correlated position of the tines applying fertilizer in rows with a spacing of 25 cm and coulters sowing cereals in rows with a spacing of 12.5 cm

Rys. 5. Schemat skorelowanego rozmieszczenia zębów aplikujących nawóz w rzędach o rozstawie 25 cm i redlic wysiewających zboże w rzędach o rozstawie 12,5 cm

By arranging the tines in two rows we can use a spacing of i.e. 45 cm, typical of beet, and also used in the cultivation of rape seed sown with point seeders. The free space of the aggregate resulting from fewer tines can be used to mount an additional work tool such as the front shaft equipped with cutter, shredding residues before the tines (Fig. 6). Sowing of beet or rape seeds accurately in the tine trace ensures good development of the pile root system deeper into loosened soil.





Source: own work / Źródło: opracowanie własne

Fig. 6. Schematic diagram of the correlated position of the tines applying fertilizer and coulters sowing rape or beet in rows with a spacing of 45 cm

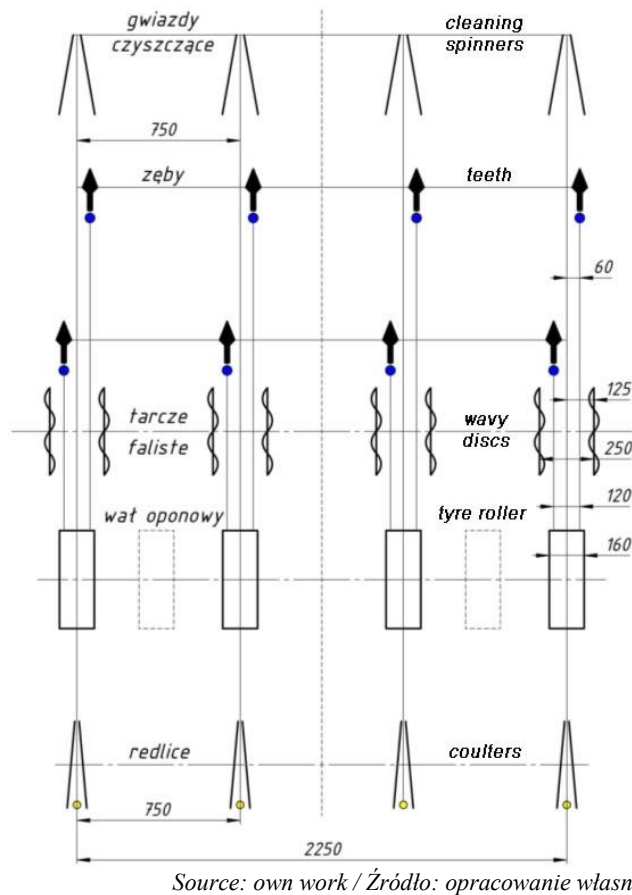
Rys. 6. Schemat skorelowanego rozmieszczenia zębów aplikujących nawóz i redlic wysiewających rzepak lub buraki w rzędach o rozstawie 45 cm

By arranging the tines in two rows we can also use a 75 cm spacing, typical of maize sowing. In the free space of the unit elements (such as stars cleansing the seed strips and corrugated disks) can be assembled, which together with tines will provide standard strip-till on the fields without prior cultivation. Unlike standard solutions in the seed strip, not one but two tines can be set, and seeds can be sown between the traces of their work (Fig. 7) in a strip cleared from crop residue. The deep soil loosening and application of fertilizer on both sides of the maize row should be conducive to the steady development of its root system.

## 5. Summary

Aggregates adapted for localized fertilization during tillage or sowing-tillage activity are equipped, among other things, with tines, which allow for deep (up to 35 cm) in row soil loosening and subsoil application of fertilizer. In standard strip-till, seedlings are planted in rows with large spacing, seeds are sown exactly in the traces of tines, which is particularly beneficial for plants with pile root systems. The adaptation of the strip-tillage and subsoil fertilization principles for sowing cereal, characterized by the beam root system, has resulted in modifications in the placement of their seeds. They are sown in strips aligned with rows of fertilizer, whose spacing is often larger than standard agro-technical recommendations, or in wide strips whose axes overlap with rows of fertilizer. Cultivating units can be

adapted to the localized fertilization of different plants by varying the number and spacing of the tines on the frame, in this way they correlate with the seed rows and all the plants have equal access to the deep loosened soil and the fertilizer placed therein.



Source: own work / Źródło: opracowanie własne

Fig. 7. Schematic diagram of the correlated distribution of tines applying fertilizer and coulters spreading maize in rows with a spacing of 75 cm

Rys. 7. Schemat skorelowanego rozmieszczenia zębów aplikujących nawóz i redlic wysiewających kukurydzę w rzędach o rozstawie 75 cm

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