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Quality Criteria of Stubble Cultivation and Drilling on the Conservation Tillage Systems

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Abstract: Tillage is any physical soil manipulation which changes structure of the soil, kills weeds, or rearranges dead plant materials. Proper tillage is the least tillage necessary to produce the desired crop as efficiently as possible. Too much tillage overpulverizes too much of the soil and speeds up loss of soil moisture; it hastens the loss of organic matter, and in many cases buries too much of the plant residues. No-tillage has economical and ecological advantages in some areas compared to conventional plow tillage. But straw residues could disturb the seed placement. Straw residue management prior to drilling has an important influence on the success of individual drills and of the technique. Options exist in any given situation to vary the quantity of loose material and its length. Quantity adjustment can be achieved by residue removal through baling or grazing or by adjusting stubble height either pre or post drilling. Length can be varied with all types of residue through chopping by tractor mounted or by combine mounted crop chopper.
This presentation is concentrated on two points:

- Agrotechnical principles of different straw management systems in case of heavy or normal plant (straw) residues.
- Quality criteria of straw management systems in combination with different drills (sowing directly into the stubble of the previous crop without disturbing the soil structure, or sowing after stubble mulching operation)

Key words: Direct seeding, stubble cultivation, straw residue management, crop chopper

Koruyucu Toprak İşleme Sistemlerinde Anızın İşlenmesinde ve Ekiminde Kalite Kriterleri

Özet: Toprak işleme, toprak strüktürünü değiştiren, yabancı otları yok eden, ölü bitki artıklarını yeniden düzenleyen fiziksel toprak manipülasyonlarıdır. Uygun toprak işleme, arzulanan bitkisel üretimin olabildiğince az işlemle yapılabilmesini sağlayan toprak işlemedir. Aşırı toprak işleme, toprağı çok fazla parçalar, toprak nemi ve organik madde kaybını hızlandırır, bitki artıklarının toprağa fazla gömülmesine neden olur. İşlemesiz tarım, bazı bölgelerde, pullukla toprak işlemeye göre ekonomik ve ekolojik kazanımlara sahiptir. Ancak, bitki artıkları, tohumun ekiminde zorluklar yaratabilir. Ekim öncesinde, tarladaki bitki artıklarının idaresi, ekim makinelerinin başarısında önemli etkiye sahiptir. Bitki artıklarının miktarına ve parça uzunluğuna göre değişen çözüm yolları vardır. Tarladaki bitki miktarının ayarı, balyalama veya otlatma ile veya ekimden önce veya sonra anız yüksekliğini değiştirerek yapılabilir. Bitki sapı uzunluğu, traktöre veya biçerdövere monte edilen sap parçalama makinesi ile değiştirilebilir.
Bu bildiri, iki konunun açıklanmasını amaçlamıştır:

- Ağır veya normal bitki örtüsü yoğunluklarına uygun, değişik bitki materyali idaresinin agroteknik prensipleri,
- Değişik ekim makineleri ile kombine edilmiş bitki materyali idare sistemlerinin kalite kriterleri (toprağı örselemeden bir önceki bitki artıklarının içine doğrudan ekim veya anız malçlı toprak işleme sonrası ekim v.b.)

Anahtar kelimeler: Doğrudan ekim, anız malçlı toprak işleme, bitki artıklarının idaresi, sap parçalama makinesi

INTRODUCTION

The amount of crop residue that remains on or near the soil surface is an important factor in controlling erosion from cultivated fields. According to the classification of the U.S. Soil Conservation Service, tillage systems are collected in three main categories such as conventional tillage, reduced tillage and conservation tillage. The sub-groups of the conservation tillage are, the mulch tillage, ridge tillage / ridge till, stubble planting (for main and second crop) and direct sowing (no-tillage= continuous no-till= zero tillage= direct drilling= direktsaat) (Önal, 2005). The value of percent residue cover or the amount of plant residues per hectar in conservation tillage is higher than 30% or 1120 kpf ha^{-1} , respectively. Up to 12 t ha^{-1} stalk yield, increasing the width of combine and slope of land harvested, create obstacles to the uniform distribution of chaff and straw on the field. The transverse distribution uniformity value (CV, %) of straw and chaff on the field could be higher than 80%, especially working with the big combine width (> 6 m) (Figure 1). According to the criteria of DLG (Deutsche Landwirtschaftliche Gesellschaft), the permissible value of transverse distribution uniformity of straw and chaff on the field after combine harvesting is 20%, and the transverse distribution uniformity does not exceed the maximum 30% (Vosshenrich, 2006b)

During the harvest, crop residue as straw and chaff must be spread as evenly as possible. As conversation tillage systems become more common and there is increased demand for good residue distribution, combines may come equipped with improved straw spreaders plus chaff spreaders and options available for today's combines. The combine-spread width should be equal the entire width of the cut. Using a cutter header higher than 6 m of cutter width or a double swath makes uniform spreading more difficult (Lücke et al., 2004). Figure 2 shows the transverse straw and chaff distribution of combine with 7.5 m of cutter header.

Some requirements to improve the residue distribution of combine mounted straw shredder and spreader could be listed as follows:

- Proper and uniform chopping of straw,
- Proper longitudinal and transverse stem-straw distribution on the field behind the combine at the harvest,
- Spreading the harvest waste and volunteer weed seeds on the field after chopping,
- Less affected straw spreading from side-wind effects to maintain the uniform straw distribution.
- To improve the processing efficiency of stalk shredder (crop chopper), in the last ten years, the rotor speed was increased to 4000 min^{-1}, the peripheral speed of the knife reached to limit value of 100 m s^{-1} and as a result power requirement of combine increased (Forche et al, 2003).

In the processing chain of cereal from planting to harvest, decreases the combine header height, increases the energy consumption and decreases the quality of work (Figure 3). After combine harvesting, it is possible to chop the tall stubble in the field to the short-stemmed straw by using the hammer type crop chopper. However, in this case, more energy is spent and time requirement will be high (Vosshenrich, 2006a). In addition, crop chopper needs high logistical requirements (additional tractor and other drivers, high labor requirement, climatic conditions do not allow work, the necessity of working in dry conditions, etc). On the contrary, when more rainfall occurs at the period of extreme rainfall in the region, the height of combine header must be increased. As a result, an increase approximately 30% in field capacity and a decrease in power requirements of combines can be achieved. For example, if the shredder mounted combine has 5.1 m cutter width, decreased the cutter header height of combine from 40 cm to 15 cm, increased the power requirement of the straw shredder from 35 kW to 75 kW and 10 liters more fuel consumption per hectare has been recorded (1100 kg ha^{-1} of grain yield, 21% straw moisture and 16.5% grain moisture content of wheat, 4.5 km h^{-1} of forward speed on the run during the harvest) (Vosshenrich, 2006a). The cutter of the combine header and knives of the shredder are protected from stone damage by increasing the mower height from 10 cm to 20 cm.

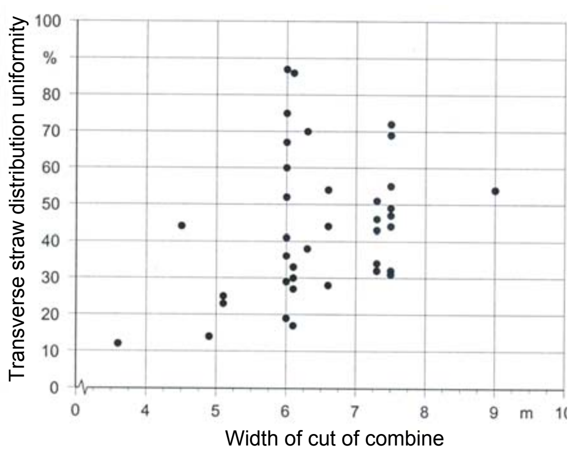

Figure 1. Transverse straw and chaff distribution uniformity of combines for various header width (Vosshenrich, 2006b)

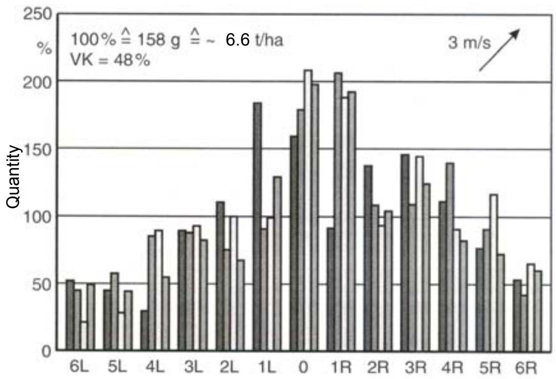

Figure 2. Transverse straw and chaff distribution of combine at 7,5 m combine header width (Vosshenrich, 2006b)

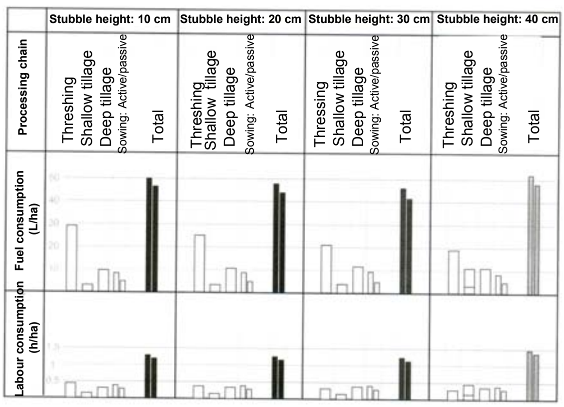

Figure 3. Fuel and labor consumption values of stubble cultivation depending on the height of cutter header of combine. Active: PTO driven; passive: ground wheel driven. (Anonimous, 2003; Vosshenrich, 2006a)

AGROTECHNICAL REQUIREMENTS, WORKING WITH STRAW AND CHAFF

The need for combine attachments or modifications for a uniform straw and chaff distribution depends on the tillage system planned for the next crop. The time interval between the harvest time of previous crop and sowing time of next crop determine the kind of soil tillage machines and residue management. If cereal is followed by winter crops (rapeseed/cereal), farmer selects the tillage machines which decompose the stem and straw rapidly. In contrast, if cereal is followed by summer crops (sugar beet, maize, potatoes, peas), the first aim of the farmer is to protect the soil from soil erosion during the winter season and to conserve the soil moisture throughout the year. In this case, tillage machine which decompose the straw slowly is selected (Figure 4).

The contributing factors affecting the stem / straw decomposition rate are given as follows:

- The degree of straw (counter knife and saw tooth blade increase the degree of straw),
- Stem/straw length (longer stem (10 cm) needs more time than shorter stem (3 cm) to decompose in soil).
- Mixing depth of straw (the lowest decomposition rate is observed on the surface (Figure 5)

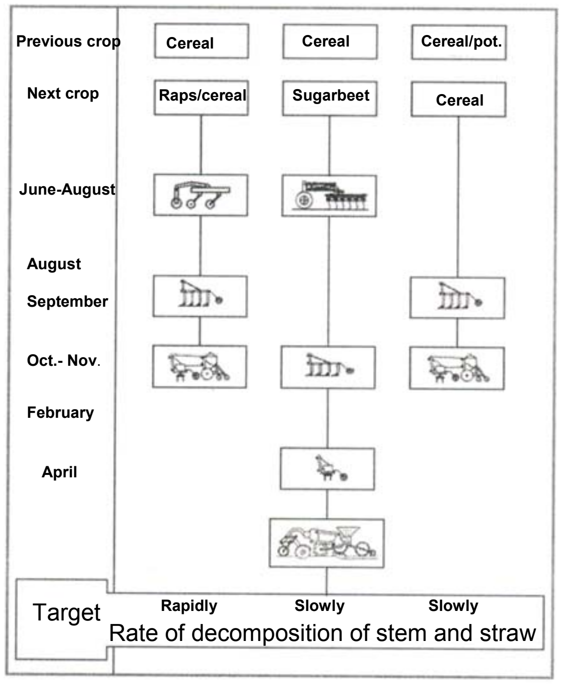

Figure 4. Processing chains of conservation tillage for various crop rotation systems (Gattermann et al., 2010)

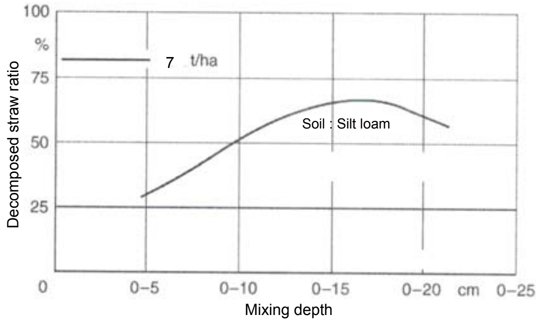

Figure 5. The relationship between depth of mixing and straw decomposition (Gattermann et al., 2010)

In the processing of conservation (plowless) tillage, three strategies are possible to manipulate the stem/straw (Figure. 6):

1. The separation of stem/straw and seed: This possibility is realized in direct sowing **(DS)** by using the narrow tine or duct foot heavy cultivator which develop the sufficient lifting force to shear the narrow band of top soil. Thus, an amount of capillary water provided from the lower soil layers will alleviate the effects of drought. In general, toxic chemicals formed from the decaying of straw and chaff could not affect the seed germination and field emergence. Seeds are sown in the straw, chaff and soil mixture at the base of rotovator. This compacted zone may be beneficial or harmful depending on the soil type, soil moisture and soil conditions at the time of tillage.

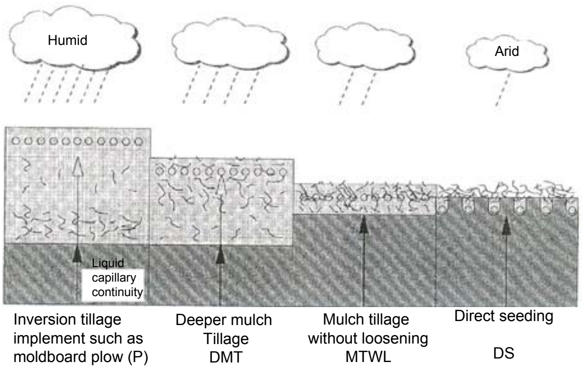

Figure 6. Seed, straw and chaff positioning in different soil tillage systems (Gattermann et al., 2010).

2. Shallow cultivation of straw: By the mulch tillage without loosening the soil **(MTWL),** the length of straw threshed by combine mounted straw shredder should be shorter than 1 cm to get a higher field emergence rate and crop improvement. This system requires an adequate technical equipment and costly works. Spring sowing could be realized by using today's technological opportunities at lower than 5 t ha $^{-1}$ straw and chaff density (Figure 7).

3. In order to reduce the residue density in the soil layer from 12 t ha $^{-1}$ to workable value, deeper mulch tillage is required **(DMT).** By this way, the straw in the soil volume is diluted. If the stalk and straw are not mixed uniformly in the soil profile, straw and chaff block (straw and chaff mattress) occurs. This straw and chaff blocks in the soil profile prevent movement of capillary water; in humid conditions forms in the straw and chaff mattress a toxic harmful chemicals such as, patulin, vinegar acid, propionic acid which kill the germinated seeds. (Mc Calla, 1967). As a general rule, in order to decompose the straw properly, tillage depth should be increased 2 cm per 1 t ha $^{-1}$ straw density.

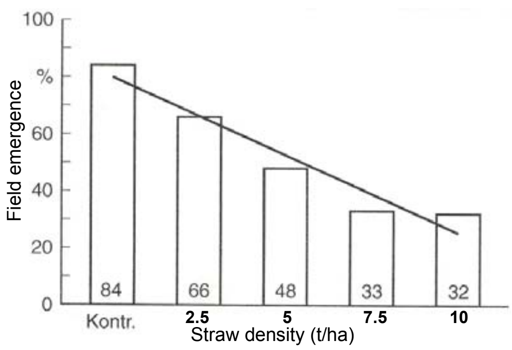

Figure 7. Relationships between the straw density and field emergence (Gattermann et al., 2010).

QUALITY CRITERIA OF STUBBLE CULTIVATION AND DRILLING ON THE CONSERVATION TILLAGE

Seeding mechanism of direct seeding machines sows the seeds according to single-seed, band, drilling, spreading or cluster seeding methods. Therefore, the performance tests of seeder mechanism and fertilizer units must be made in according to Test Books named as Agricultural Mechanization Equipment and Machines - Test Principles and Methods" (Anonymous, 1999).

Unlike traditional sowing machine, plant residues left on or near the soil surface and residue distribution in the soil profile must be measured in the experiment according to the requirement of the concept of stubble or direct sowing machine:

- The amount of horizontally and vertically distributed residue by the straw shredder and spreader mounted externally or internally at the back of the combine must be measured. With no-till and minimum tillage systems, uniform combine residue distribution can greatly improve crop establishment and yield potential. Prior to 1985, combines were not designed to spread the chaff or fines that drop from the shoe section of the combine. As conservation tillage systems become more common and there is increased demand for good residue distribution, combines may come equipped with improved straw spreaders plus chaff spreading features. Well distributed straw on the field surface after combine harvest is an important part of residue management. For this reason, the residue distribution on the field after harvest must be evaluated as mentioned below:

a) Transverse straw and chaff distribution of combine is measured on the field surface before planting. The variation coefficient of the transverse straw and chaff distribution which is calculated from the amount of straw and chaff collected from 50 * 50 cm squares of a grid by hand or from the 60 cm diameter of circle area by the vacuum must be less than 20% (Table 1), (Figure 8)

b) The transverse straw and chaff distribution chart is prepared from the measured values and straw and chaff density (kgf ha $^{-1)}$ is calculated.

c) In order to determine the transverse distribution of straw on the field quickly, the residue on the field is collected from the 1.5 m of band in the form of windrows by hand or by pitchfork, then the amount of straw and chaff in each meter width of windrow is weighted.(Figure 9). From this values, the transverse distribution graph is obtained.

Percentage residue cover is the percentage of soil surface covered by pieces or fragments of plant material as seen by a nadir view and herein termed „cover", given in units of „% cover" (Morrison et al, 1995). For this purpose, the line -transect or wheel (wheel residue) method were used. In the United States, nine devices (five of them straight line method, 4 of them wheel method) were used to visually measure percent residue cover on field sites in 7 states. The residues were from crops of wheat, corn, cotton, sorghum, soybeans, and sunflowers. Even though the fields visually appeared to be uniformly covered within measurement sites, data from each observer using the same measurement device revealed that there was variation of cover ranging from 7 to 20 percentage points. The variation among the observers was also greater than expected. The observers were mostly trained, USDA- Natural Resources Conservation service employees, yet observer variations were nearly nine percentage points when using the same device on the same site. The measurement errors of the line transect or wheel method became higher when the amount of soil coverage was high.

Figure 8. Determination of the transverse straw/chaff distribution after combine harvesting using the collection containers (60 cm Ø round or 50 * 50 cm square grids)

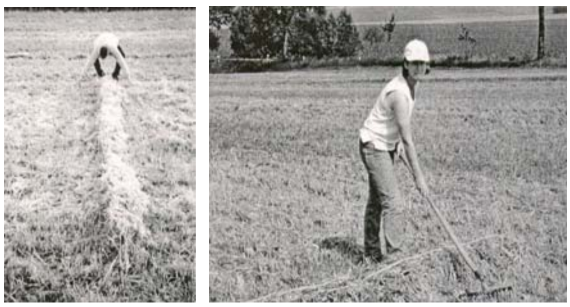

Figure 9. Quick way to build the windrow by hand or pitchfork in the field.

Table 1. Transverse /longitudinal distribution uniformity (CV, %) of straw and chaff for good seedbed preparation or plowing after combine harvesting or baling operation (Schwarz and Chappuis, 2007).

CV (%)	Evaluation	Tilling with plough	Suitability to stubble mulching seedbed	Direct seeding
CV < 20	++	x	x	x
20 ≤ CV < 30	+	x	x	(x)
30 ≤ CV < 40	0	x	(x)	
40 ≤ CV < 50	-	(x)		
CV > 50	_			

Evaluation scale: ++/+/0/-/_ (0- standard); (x)= conditionally suitable; x = suitable

- Corn stalk has to be chopped by crop chopper before sowing because at harvest time the corn crop reaches 2 to 2.5 meter height. (Anonymous, 1975; Önal, 2005). Chopping accelerates the breakdown and decomposition of stalk. First of all, it is important a careful study on alfalfa (Medicago sativa) and Red clover (Trifolium pretense), in order to prevent the emergence of volunteer seeds in Spring.
- Stems in the field chopped by stalk shredder is collected from grid panes 50 * 50 cm in size (for this purpose vacuum cleaner or a cyclone with a suction system can be used). The collected residue is classified by round-hole sieve set (2-4-6-8-16-30 and 67 mm hole diameter) vibrated by hand. The results are evaluated in Table 2.
- In plowless tillage, the stalk length should be provided by crop chopper under 5 cm (3 cm for the best in the stalk length) for a good settle of soil (Quwerkerk and Perdok, 1995).
- In spring sowing, the appropriate evaluation criteria to prevent erosion are given in Table 3.

The recommended performance evaluation of pioneer organs worked in front of the furrow opener such as residue fingers, fluted discs, straight or wavy discs, triple disc etc. or seedbed preparation machines are given below:

Table 2. Evaluation criteria of straw length for seedbed (Schwarz and Chappuis, 2007).

Greater than 100 mm stalk length (%)	Evaluation	Plowing in Autumn	Suitability to mulched seedbed	Direct seeding in Autumn
ratio < 5	++	x	x	x
5 ≤ ratio< 10	+	x	x	(x)
10≤ ratio< 15	0	x	(x)	
15≤ ratio< 20	-	(x)		
ratio ≥ 20	- -			

Evaluation scale: ++/+/0/-/- - (0-Standard); (x) = conditionally suitable, x = suitable

Table 3. Appropriate evaluation criteria to prevent erosion in spring sowing (Schwarz and Chappuis, 2007).

Greater than 100-175 mm long stalk ratio (%)	Greater than 175 mm long stalk ratio (%)	Assessment for erosion reduction in spring sowing
< 15	<5	- -
15 ≤ ratio < 40	<5	0
40 ≤ ratio < 60	<5	++
ratio > 60	<5	0

Evaluation scale: ++/0/- - (0= standard)

- After planting, soil profile is opened symmetrical by 50 cm length and 30 cm depth perpendicular to the axis of row. Gridiron is placed vertically (or horizontally) in this profile (Figure. 10). Gridiron is made of 3 mm diameter stainless steel wire configuration, 50 cm long and 30 cm high. It has square grids in size of 4.5 * 4.5 cm. Soil may need to be moistened with a little water to ensure a stable work in dry sandy soil.
- Straw volume in each grid is observed carefully, and straw amount in each grid is scored relatively 0-10-25-50-75 and 100 points. (0 = no straw, 100 = grid straw filled). It is advisable to continue the scoring with the same person.
- Gridiron is placed horizontally on the row to horizontal scoring. Straw volume in each horizontal grid is scored in the same way.
- Evaluation will be made after vertical and horizontal scorings. Reviews to make it more understandable, the examples given in Figure 11 will be used:

Figure 10. Determination of straw distribution on the surface or in the soil profile by using the 4.5 * 4.5 cm gridiron system.

a) The evaluation of vertical profiles: The vertical straw transverse distribution uniformities (CV) for 0-5, 5-10 and 10-15 cm soil layers are found 69%, 117.1% and 316%, respectively. Vertical total straw covering score (ΣDSKP) is taken from Figure 11 (ΣDSKP = 690).

b) Horizontal straw profile assessment: Horizontal average straw density score (x_y = 45, standard deviation S = ± 15.81), horizontal transverse straw distribution uniformity (CV = %35.13) and horizontal total straw cover score (ΣYSKP = 450) are found. These values are compared with the horizontal straw distribution uniformity values obtained another mulch tillage trials.

c) The sum of horizontal and vertical straw covering scores give us the straw index (SI):

$$SI = \Sigma YSKP + \Sigma DSKP = 450 + 690 = 1140$$

Straw index and straw density (kg ha $^{-1)}$, are taken into account in the assessment of running organs of sowing and tillage machines. For this purpose, in-row measurement described above which is done perpendicular to the row in 50 cm band width, are repeated also in inter-row spacing. Comparing the horizontal and vertical covering scores and straw indexes obtained from in-row and inter-row measurements, the performance of seedbed preparation machines; furrow opener, pioneer organs attached in front of the furrow opener and seed covering devices of direct seeding machines could be evaluated.

Using the average straw density points for each soil layer ($\overline{X}_d$) (Figure 11):

- Vertical average straw covering score (23), standard deviation (S = 20.67) and variation coefficient (CV = 89.87%) is calculated.
- Average straw depth ($\overline{d}$):

$$\overline{d} = \frac{\Sigma \overline{X}_d \cdot d_d}{\Sigma X_d} \qquad (1)$$

is found. In Equation 1, $\overline{d}$ is an average of straw depth; $\overline{X}_d$ is an average of straw density points for each soil layer. Using the values given in Figure 11, an average straw depth can be calculated:

$$\overline{d} = \frac{42 \cdot 2,5 + 26 \cdot 7,5 + 1 \cdot 12,5}{42 + 26 + 1} == 4,53 cm$$

Vertical straw distribution uniformity is found as a 89.9% (Figure 11).

Straw index = SI = ΣYSKP+ΣDSKP=450+690=1140

Xy= 45 **S= 15,81** **CV= 35,13%** **ΣYSKP= 450**

ΣYSKP=450	50	75	50	50	50	25	50	50	25	25	$\overline{X}_d$	S	CV,%	ΣXd
dclass 2,5	10	10	25	50	50	25	25	50	100	75	42	29,98	69	420
7,5	0	75	25	10	25	0	0	75	50	0	26	30,44	117,1	260
12,5	0	10	0	0	0	0	0	0	0	0	1	3,16	316	10
17,5										Ort S VK d	23 20,7 89,9 4,53		ΣDKP	**690 ΣDSKP**

Figure 11. Horizontal and vertical straw covering scores and straw index on a 40-50 cm wide strip of row (Original).

CONCLUSION

Reducing the amount of straw residue in a field to an operable level, but maintaining adequate cover for erosion protection is a key objective of a conservation farming system. In reduced tillage systems it is preferable to have straw residue uniformly distributed, broken into small fragments and mulched into the soil surface. This protects the soil from erosion and minimizes nutrient tie-up and problems with residue plugging machinery. In no-till systems straw distribution is equally important, but must be achieved solely by straw spreading while combining. The amount of straw produced is a factor in choosing and designing tillage and residue handling techniques. This article offers quality criteria of straw management systems in combination with different drills (sowing directly into the stubble of the previous crop without disturbing the soil structure, or sowing after stubble mulching operation)

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John Deere 96/80 mit Premium Haecksler (6,7 m)
John Deere 96/80 mit Standard-Haecksler (6,7 m)