Short Communication

Soil Compaction as the Possible Cause of Wilting and Premature Ripening of Sunflower

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Abstract

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Brown patches of the size from several square metres to hectares or individual dying plants appeared in otherwise green stands. Affected plants wilt and ripen sooner than healthy ones, causing them to have smaller seeds or none at all in the central part of the heads. Under extreme conditions the plants wilt and die in early summer when they are less than 50 cm high. No infective agent was found as a causal organism. Disturbed plants root only in the upper 10 cm layer of the soil, or just below the surface. Poor soil structure and aeration are supposed to be responsible for limited root development. It prevents a sufficient supply of water to the plants during the hot and dry summer months and causes them to wilt. In contrast to cereals, winter rape and some other field crops that ripen during July, sunflower grows very intensively and needs a good supply of water even towards the end of August and in the first half of September. Thus, sunflower plants rooting only in the shallow uppermost layer of the soil suffer much more than other crops from hot and dry conditions.

Keywords: sunflower; roots; premature ripening; soil compression; soil aeration

Stem necroses, subsequent wilting of parts or whole sunflower plants, and even their death, are the known symptoms caused by several fungal species (e.g. *Sclerotinia sclerotiorum*, *Phoma macdonaldii*) and are fully described in the relevant literature.

Yet in the Czech Republic, premature wilting and dying of plants that cannot be attributed to any of the known detectable pathogens are the most frequent. Similar symptoms can be connected with Verticillium-wilt, very rare in the Czech Republic, or with the charcoal disease of roots and stem base caused by the warm climate pathogen *Macrophomina phaseolina* (Tassi) Goid., newly reported in 1999–2002 under conditions of extremely hot and dry weather (Šárová *et al.* 2003). Furthermore, these diseases can be distinguished visually from non-infectious disorders.

Wilting and dying of plants without any known cause of an infection agent were found during

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1996–2005. The disease is very common on almost every field in the sunflower growing regions of the Czech Republic. The aim of the present study was to describe the symptoms of this disease and to suggest its causes.

Symptoms

Wilting and premature ripening plants are usually visible after flowering when individual plants, groups of plants or a large proportion of the field are thus disturbed (Figure 1). While healthy plants are green and the seeds in their heads are still developing, affected plants wilt and dry up. A milder form of this disease can also be described as premature ripening, with affected plants developing smaller heads and also smaller seeds. Sometimes the much smaller kernels consist of the testa only without any reserve substances inside (Figure 2). In even more severe cases the plants wilt sooner than the seeds of the florets in the central part of the heads develop; only remains of the dry florets can be found there (Figure 3). The most severe symptoms of the disease were found in 2001 near Slaný. Already in June, individual young plants began to wilt, the apex (Figure 4) and eventually the whole plant died. These plants were less than 50 cm high (Figure 5).

The root system of plants suffering from this wilt lies usually in the upper 10 cm soil layer. The taproot is bent at a right angle (Figure 6) or the plants have no main root but only a bunch of roots in the uppermost layer of the soil (Figure 7). Sometimes their taproots grow deeper, making use of some non-homogeneity or cracks in the soil, but are not able to develop a normal root system there with side roots. The most affected plants are rooting just under the soil surface (Figures 4 and 5).

Occurrence

Sunflower stands usually still appear very healthy during flowering. However, despite regular plant spacing, unexpected differences in head size and stem diameter of individual plants could be found in almost all of the inspected fields. Most of the weaker plants suffer from wilting later. In contrast, flowering stands at localities where this disorder did not appear later, were very notable for their uniform size of plants and heads.

Wilting and dying plants can usually be detected after flowering when individual plants, groups of plants, or large proportions of the field are affected. While healthy plants are green and the seeds in their heads are still developing, affected plants wilt and dry.

Brown patches of dying plants, measuring from several square metres to hectares, can be seen from afar (Figure 1). Inspections in the green part of the stands reveal individual or several neighbouring dying plants in a row next to healthy plants (Figure 8) and vice versa – amongst dry and brown plants an individual healthy plant can sporadically be found. Patches of wilted plants usually occur on depressions of the terrain, often small and flat. In contrast, charcoal disease occurs on the driest parts of the fields, e.g. on the hills.

Possible causes of the wilt

Poor root development seems to be the most important cause of sunflower wilting and premature ripening. Sunflower is most sensitive in its response to disturbances in root development. While the cereals, winter rape etc. mature during July, sunflower grows very intensively and needs a good supply of water even at the end of August, in some years even later. Therefore, sunflower plants with roots only in the uppermost layer of the soil suffer much more than other crops in a hot and dry summer when their root system cannot supply water from deeper layers.

The effect of poor root development on plant growth is dependent on weather conditions. Whereas its negative effect is less pronounced in years or periods with sufficient soil moisture, in the extremely dry spring of 2001 it caused young plants to die even as early as the end of June. In dry years this type of wilting is able to cause high losses, perhaps higher than all fungal diseases are able to cause together.

Under moist conditions plants do not suffer from shortage of water and nutrients so much, because the difference between water use by plants with good and poor roots is not so large. In the extreme, i.e. if the soil is soaking wet after flowering, the plants are not able to carry the heavy heads and they fall over uprooted.

The disordered plants (with the exception of dying young plants) are of normal height, but their stems are thinner and the heads have a smaller diameter. This resulted from the functions of the plant being disturbed much earlier, before the wilting and dying of the plants became visible.

Figure 1. Patches of affected plants in the field at the beginning of the ripenning

Macrophomina phaseolina was also found in the roots and stem base but only at some localities and not in all the wilted plants. *M. phaseolina* attacks mainly water-stressed plants. A correlation between the shallow root system, water stress, and the incidence of *M. phaseolina* seems to be obvious.

Possible causes of inadequate root development

The effect of soil conditions on the development of abnormally shaped roots has been studied especially in root crops. Multiple root formation and forking decrease the market quality of carrots and other root vegetables, and hamper the processing of sugar beet. The reasons for abnormal roots are not only an impervious soil layer or the lack of oxygen due to poor soil aeration, but also soil-borne diseases, nematodes, insect pests, pesticides or fertiliser injury (Davies & Raid 2002).

Very few data on root development in sunflower are available. Terbea and Vranceanu (1988) found high variability in root development caused by both heredity and environmental factors, but the genetic differences were usually annihilated under field conditions. The authors described very different morphological structures of the main root and lateral roots, but they did not mention

Figure 2. Achenes from healthy (left) and from the disturbed plant (right)

Figure 3. Heads of healthy (left) and of the plant suffering by wilting and premature ripenning (right) with dry florets in the middle of the head

Figure 4. Necrotized apex of young olant with very shallow rooting

Figure 5. Died young plant with tap root grown horizontally

Figure 6. Pipe-like tap root of sunflower. Abundant adventitious roots originating from the stem base indicate unsuitable soil conditions in the compacted deeper zone

the situation when the sunflower taproot was not able to penetrate to the deeper soil layers at all. On this aspect we observed no differences between the hybrids.

Nor did we find any mention of plant breeding aimed at the root system of sunflower. However, important results have been obtained in maize breeding. The architecture of the maize root system influences its ability to withstand uprooting (Stokes *et al.* 1996). Root traits cannot easily be used during rapid selection of large numbers of maize lines for resistance to lodging, so that vertical pulling resistance is used to evaluate root system characteristics. The resistance of maize lines to lodging, to low nitrogen water stress and nutrient uptake are correlated (Kamara *et al.* 2003).

Figure 7. Bunch of roots which has developed only in the uppermost layer of the compacted soil

Figure 8. Several disturbed plants in the stand

It is known that soil with a high silt or clay content may compact upon drying, resulting in increased resistance to root expansion or elongation. If the growth of the young taproot is restricted by an impervious layer or other obstruction within the first few weeks following germination, the root may grow at an angle (Davies & Raid 2002).

The main reason for inadequate root development of sunflower appears to be soil compaction and poor soil aeration. A degraded soil structure is regarded as a consequence of "modern agriculture" with its heavy mechanisation, heavy transport loads, and small amounts of farmyard and green manure.

Compaction does not decrease total porosity, but increases the proportion of capillary pores and decreases the proportion of large pores which enable the exchange of gases. (Porosity minus capillary capacity = minimal air capacity). The minimal air capacity of samples taken from the soil of a field with wilted young plants reached 1.5–4.7%, while the optimal value should be higher than l0% (Veverka *et al.* 2002).

The disturbed root development just described were found on fields with "conventional" soil preparation (deep ploughing in autumn). No field sown using the minimal no-till technology was inspected. From other crops it is generally known that compacted roots are often found in fields where minimal tillage was used.

Only at a few localities was there no wilting, no premature ripening and no disturbed root growth in sunflower. These were places with good soil structure, e.g. in the Žatec region on soil on a volcanic substrate with a very good structure where quite an ideal root system developed, on the fields of the Research Institute for Plant Production, Prague-Ruzyně, and on the plots of Mendel University of Agriculture and Forestry, Brno. The two latter localities were spared the deleterious effect of soil compaction through heavy mechanisation.

Healthy root development plays a crucial role in yield production, while the root:stem ratio has almost constant values under the same conditions. It means that under equal conditions, small heads with poorly developed seeds reflect poor roots. Soil compaction affects not only the size of roots but even their shape, and consequently the whole plant. This is the reason why the destruction of the soil structure has become a general problem. High compaction increases the bulk density and deteriorates the soil structure; low porosity and a deficit in air limit the yield potential and production quality (Dexter 1986).

The main cause of deterioration of the soil quality in the Czech Republic is compaction. Penetrometric resistance in sugar beet fields was increasing gradually from the beginning of the vegetation until harvest. Repeated passages of machines across the fields had a strong impact on soil compaction down to 52 cm. The chlorophyll content and root weight of sugar beet showed the relatively closest negative correlation with penetrometric soil resistance (Zahradníček *et al.* 2001).

Soil compaction seems to have a decisive effect on root growth, plant development and yields. If the tip of the taproot is destroyed, new roots, which develop above the decayed region, help the plants to recover, and that is why this problem was stressed in root crops but overlooked in others. Besides soil compaction, an important role may also be played by other factors like water/air ratio in the soil during spring, salts content of the soil, herbicides in deeper zones etc. Nevertheless, sunflower is the plant which responds most drastically to poor root development by wilting and dying because shallow roots cannot supply the necessary water during the hot and dry summer months.

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