WHEAT PRODUCTION GUIDELINES
FOR SMALL-SCALE FARMERS

The information in this booklet is the result of scientific research and is supplied in good faith. The institutions involved therein disclaim any legal liability as a result of the implementation of recommendations in the booklet.

Copyright © Agricultural Research Council 2009

Coordinated and edited by:
Dr. Eric Morojele and Elri Burger

Layout, design and printing:

infoworks
(018) 468-2716
www.infoworks.biz

ARC-Small Grain Institute would like to thank:
The Winter Cereal Trust for the financial support from which the research results were determined
Acknowledgement

Many professionals in Small Grain Institute, with different areas of specialities, assisted in compiling these production guidelines and our sincere gratitude are extended to them. They are as follows:

Willem Kilian  Programme Manager  Production Systems Services
Dr Goddy Prinsloo  Entomologist  Plant Protection
Dr Vicki Tolmay  Entomologist  Plant Protection
Dr Willem Otto  Agronomist  Production Systems
Dr John Tolmay  Soil Scientist  Production Systems
Dr Annelie Barnard  Crop Physiologist  Production Systems
Dr Eben von Well  Plant Breeder  Plant Improvement

ARC-Small Grain Institute
Private Bag X29
Bethlehem
9700
www.arc-sgi.agric.za
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>04</td>
</tr>
<tr>
<td>2. Morphological characteristics</td>
<td>06</td>
</tr>
<tr>
<td>3. Crop growth and development</td>
<td>08</td>
</tr>
<tr>
<td>4. Climatic requirements</td>
<td>12</td>
</tr>
<tr>
<td>5. Agronomic practices</td>
<td>14</td>
</tr>
<tr>
<td>6. Crop protection</td>
<td>28</td>
</tr>
<tr>
<td>7. Storage and marketing</td>
<td>54</td>
</tr>
<tr>
<td>8. Other useful information</td>
<td>56</td>
</tr>
</tbody>
</table>
Wheat Industry in South Africa

Wheat is an important cereal crop ranking second after maize in terms of area planted and production. It is grown on an area of 750 000 to 1 000 000 ha, which produces an average annual production of 1,5 to 2,5 million tons. The provinces that produce wheat are Free State (47%), followed by the Western Cape (39%) and the Northern Cape (11%). Other provinces produce smaller amounts. The total requirement for wheat in South Africa is 2.7 million tons, which is higher than the total production. In order for South Africa to meet its requirements, wheat is imported from Argentina, United States of America, Germany, Canada, Ukraine and the United Kingdom.

Bread wheat is produced in large quantities in comparison to durum wheat. It is used for making leavened, flat and steamed bread, cookies, cakes and fermented alcoholic beverages such as beer, vodka and ethanol. Durum wheat is used for biscuits, pasta, macaronis, noodles and couscous. Other by-products are utilized as feed for animals, for example, straw and wheaten bran. It is a cheap source of carbohydrates and protein affordable by many people. Wheat grain contains carbohydrates (69%), protein (14%), calcium (43%), niacin (4.6%), fat (2.2%), thiamin (0.57) and riboflavin (0.12%).

Origin and distribution

Wheat is believed to have originated in the Near East, in the areas now occupied by Syria, Turkey, Afghanistan, Iraq and Iran. Grains of domesticated wheat were found in the archaeological remains in Ali Koshi in Iranian Khusistan, dating back to 6500 BC, as well as in Anatolia in Turkey, dating back to 5500 BC.

Cultivation of wheat spread from its origin to India, Pakistan and China in the east, to the Mediterranean countries in the west and to U.S.S.R. and other countries in the north. In South Africa, Jan van Riebeeck introduced it in the middle of the 17th century upon arrival in the Cape in 1652. Thereafter it spread to Western Cape, South Western Cape and Free State Provinces.
Wheat belongs to the family Gramineae, tribe hordeae, genus Triticum. It is an annual grass made up of roots, stems with tillers, leaves, inflorescence and seeds. Figure 1 shows all the vegetative parts of the wheat plant.

**Roots** – The wheat plant has two types of roots, namely; seminal and adventitious roots that are initiated after germination. During germination, the primary root bursts through the coleorhiza and four to five lateral seminal roots emerge. These form the seminal root system that may grow up to two metres in depth and support the plant until the adventitious roots appear. Adventitious roots are associated with tiller development and are usually visible when the fourth leaf emerges and tillering starts. When compared to the seminal roots, adventitious roots are thicker and emerge more or less horizontally. Adventitious roots develop on the lower three to seven nodes. The roots that develop on the upper nodes above the soil surface may not penetrate the soil and appear as short pegs coming out of the stem.

**Stem** – The stem of the wheat plant varies in height depending on the cultivar. Four to seven internodes of the shoot elongate to form the inflorescence. The stem is cylindrical, solid with nodes and internodes. The internode elongation is complete by the time of anthesis. Internodes increase in final length from the base of the stem to the uppermost internode which carries the ear. The basal internodes are shorter than the axial internode. The strength of the stem is important for carrying an ear, which otherwise may be susceptible to lodging. Tillers grow from the stem just below the soil surface and the number of tillers in a plant ranges from 5 to 21, depending on the cultivar, plant population, sowing dates and mineral nutrition. Winter cultivars produce more tillers than spring cultivars because of low temperatures that stimulate vernalisation.

**Leaf** – The leaf is comprised of a blade, ligule, auricle and sheath. The blade is long, narrow, thin and tapered towards the tip. The sheath wraps around the stem starting from the node downward, while on the other side, it has a ligule that joins it to the blade that is over-hanging. On the sides of the joint is a thin membranous structure called an auricle. The base of the leaf on the stem is thickened to form a hard knot.

**Inflorescence (Head)** – The inflorescence that is often called an ear or spike comprises of a rachis, spikelet, floret, glumes, palea and caryopsis. The rachis is the zigzag stalk where spikelets are attached and situated at the distal end of the stem. There is a gradient of size and maturity along the ear, with the largest and most advanced spikelets situated in the middle part of the ear. Under unfavourable growing conditions, the lowermost spikelet and those at the top of the ear may be poorly developed and without fertile florets. Each spikelet bears two glumes and two to four fertile florets. The floret has two sheathing structures, namely outer lemma and inner palea that enclose two lodicules, three stamens and a carpel. The stamen is made up of a filament, which is very short at the stage and a yellow anther. The anther contains numerous pollen grains. The carpel contains an ovary that in turn contains a single ovule. Within an ovule are the embryo sacs, containing two egg nuclei, antipodal cells and polar nuclei.
As it approaches anthesis, the inflorescence is completely formed. The pollen grains and carpel are fully developed. After anthesis, the florets open, pollen is released and the carpels are pollinated and the seed develop from the union of pollen grains and egg nuclei. Approximately 86% of the flowers bloom in daylight. Flowers bloom at temperatures ranging from 13°C – 25°C. Wheat is self-pollinated, even though 1 – 4% cross-pollination occurs. Blooming begins in the spikelets slightly below the middle of the spike and proceeds both upwards and downwards. Within a spikelet, the upper flowers boom last. Under normal conditions a wheat spikelet completes its blooming within 2 – 3 days after the first anthers appear.

**Seed** – The seed of wheat is a dry indehiscent fruit. The dorsal side is smoothly rounded, while the ventral side has the deep groove. The embryo is situated at the point of attachment of the spikelet axis and the distal end has fine hairs. The embryo is made up of the scutellum, plumule and radicle. The scutellum is the region that secretes some of the enzymes involved in germination and absorbs the soluble sugars from the breakdown of starch in the endosperm. Surrounding the endosperm is a metabolically active layer of cells called the aleurone layer.

*Figure 1: Physiology of the wheat plant.*
3. Crop growth and development

The wheat crop undergoes several stages from germination to physiological maturity. Basically, there are four stages, namely tillering, stem elongation, heading and grain-filling, and physiological maturity (harvesting).

**Tillering** – It takes place approximately six weeks after emergence and this is the period when more stems come out from the crown at a mid-point between the stem and the roots. In winter cultivars, more tillers are produced than in spring cultivars, because low temperatures induce vernalisation that in turn produce a hormone called vernalin that is responsible for tillering in wheat. Photoperiodism also plays a major role in tillering. The tillers grow horizontally instead of vertically. Some of the tillers produce spikes. Figure 2 below depicts tillering stage.

**Figure 2: Tillering stage**

**Stem elongation** – It takes approximately four weeks and this is the stage where stems form internodes and increase in length and in the number of internodes. The hard knots in between the internodes become visible. The stems that were growing horizontally are now becoming erect. More leaves from the stems are unfolding, which is dependent on temperature, nutrients and moisture. In Figure 3 stem elongation is taking place.
Heading – Wheat plants have four to eight leaves in the main stem when the growing point changes from the vegetative to reproductive stage. Temperature above 30°C during floret formation causes complete sterility. Each spikelet has eight to twelve floret primordials in the central part of the spike. The basal and distal spikelets have from six to eight florets. Less than half of these florets complete anthesis, while the rest abort or are insufficiently developed before anthesis. Spikelet number is determined, varying from 20 to 30 and is highly correlated with the length of the vegetative stage. The longer the vegetative stage the higher the number of spikelets. The actual number of spikelets are determined by the reproductive stage. Figure 4 shows parts of the inflorescence. Heading stage takes approximately four weeks. Below, Figure 5 depicts heading stage.
Physiological maturity – Anthesis starts from the middle part of the spike and continues towards the basal and apical parts during a three to five day period. The proximal florets of the middle of the spikelets are fertilised two to four days earlier than the distal florets. These grains usually have greater weight. After floret fertilisation, cellular division is rapid. This period takes about 20 to 30 percent of the grain-filling period. Thereafter there is a phase of cell growth, differentiation and starch deposition in the endosperm follows. This accounts for 50 - 70 % of the grain-filling stage.
Late grain-filling stage leads to maturity that is signified by drying of the leaves and hardening of the contents of the grain. Figure 6 indicates physiological maturity of the wheat crop.

The different stages of growth in wheat are described according to Zadocks’ scale, Feeke’s code and Joubert, where major stages are divided further into intermediate sub-stages. Figure 7 below illustrates all the stages and components of yield, while Figure 8 shows the basic stages of a wheat crop.

*Figure 7: Stages of growth according to Feeke’s scale, Zadock and Joubert, and yield components of wheat*

*Figure 8: Basic growth stages of wheat*
4. Climatic requirements

Temperature
Small grains produced in South Africa are all winter crops that should be planted in autumn, winter or early spring. Cultivars that differ in growing period, day length and vernalisation requirements are available and adapted to all the production regions of South Africa. As small grains need moisture during winter, spring and early summer, it is important that water be provided to the crop during this period. In the winter rainfall region of South Africa (Western Cape Province) sufficient rainfall is usually received during the winter months to provide the needs of the crop. In the other provinces of the country no or very little rain is received during winter. Wheat produced in these areas must either be irrigated or water must be provided by soil water storage. Areas that can produce rainfed wheat in the Northern Provinces must have duplex soils with high water storage capacity so that enough water from the previous summer can be stored and be used until the first spring rains. Although irrigated wheat can be grown almost anywhere on the Highveld of South Africa, dryland production is mostly restricted to the Free State Province and surrounding areas with suitable soil. As a rule of thumb, small grains need about 300mm precipitation, spread over the growing season, to produce reasonable yield. In the case of dryland production with stored soil water, about 180mm is provided by the soil and 150-200 mm by spring rains.

Small grains in the germinating, seedling and vegetative stages are not sensitive to low temperatures and frost. Winter types require very low soil temperatures (3-4°C) for at least 10 days to 8 weeks in order to vernalise and reach their tillering potential. These cultivars can be planted at very low seeding densities (15-30 kg/ha). Spring wheat, like the cultivars planted in the irrigation areas and in the Western Cape, does not require low temperatures, but will not be damaged by low temperatures and frost during the early growth stages. Spring wheat will not tiller as much as winter types, and therefore much higher seeding rates (80-120 kg/ha) are needed in these production areas. However, all small grains are sensitive to frost in the reproductive stage (when the growth points are above ground or after the emergence of the ear). Frost during this time (usually in September and October) can cause severe damage to the crop.

Small grains can also be damaged by dry, warm periods. Heat stress is caused when drought conditions are experienced and is usually associated with high temperatures and warm dry winds. Heat stress can be particularly damaging during the flowering stage of the plant.

Rainfall
Small grains planted in the summer rainfall region (dryland and irrigation) mature in the early summer (November to December). It is during this period that rainfall and hail can cause damage to the maturing and ripening crop. Almost all cultivars are susceptible to preharvest sprouting (germination of seed in the ear) and must be harvested as soon as possible to prevent low falling number or sprouting of the crop.
Wheat that is not harvested in time can quickly deteriorate in terms of quality (reduced hectolitre mass) and become infected with fungi (mould), indicated by a change of colour in the ears (golden yellow to white to black). Hail during or after emergence of the ear can cause severe yield loss and the only recourse farmers have, is to take out insurance against hail damage.

The Western Cape receives very little rain and no hail occurs during harvest, but strong winds during this period can cause severe crop losses, especially to barley and oats. It is for this reason that these crops is swathed (cut down) before maturity and picked up with the harvester later. In the unlikely event that rain is received on a swathed crop, similar damage could occur as to a standing crop.

Planting each cultivar within the recommended planting time for each area will help to minimize the risk of damage by climatic factors such as drought, heat, cold and rain. As all recommended cultivars are tested over many seasons in each environment and all possible stress factors are taken into account when recommendations are made, keeping to recommendations will offer the best chance of getting a successful harvest.

**Soil requirements**

Small grains are in general well adapted to different soil types and can therefore be grown on all arable soils in South Africa including heavy clay soils, very sandy soils, and very rocky soils as long as the climatic requirements are met. As with any other crop, small grains thrive in fertile well-drained soils, but with good fertilisation programmes even less fertile soils can be productive. Small grains are however more sensitive to soil acidity than most crops and require a soil pH (KCl) of at least 4.5 and an acid saturation of less than 8%. Liming programmes to keep the pH at acceptable levels are an important part of small grain production in most areas. Small grains are also sensitive to very high salinity that can occur under irrigation and some highly saline soils are not suitable for production. For example an ECe (electrical conductivity of the saturation extract) of 740 mS m\(^{-1}\) and EC\(_{iw}\) (electrical conductivity of the irrigation water) of 490 mS m\(^{-1}\) will cause yield reduction of about 10% for wheat. Likewise the ECe of 1000 mS m\(^{-1}\) and ECiw of 670 mS m\(^{-1}\) will reduce the yield of barley by 10%. Most of the small grains are classified as moderately tolerant to tolerant on salinity tolerance scale.

For dryland production in the summer rainfall region, special soils with a large water holding capacity are needed to ensure sufficient soil water storage. These soils must be able to store at least 180mm water before planting and mostly consist of the duplex soil types. Soil types such as Avalon, Westleigh, Clovelly, Longlands and Pinedine have a heavy clay layer or barrier layer that prevents stored water from draining away, and are therefore suitable for soil water storage. Very well drained soils like the Hutton soil type (deep red soils) are not suitable for dryland production, but very suitable if irrigation can be applied.
5. **Agronomic practices**

**Cropping system**

From an economic and agronomic viewpoint, it is beneficial to cultivate wheat in a suitable crop rotation system. Grain yields are increased, while weeds, insect and disease problems are also substantially reduced. Good crop rotation planning is the single most important management practice determining yields and profitability. It is an investment in risk aversion. Well-planned and managed crop rotation systems decrease input costs, increase yields and spread production risks.

There is not one rotation system that will be suitable for all production regions. Every farmer must plan and develop a long-term system that is adaptable and sustainable, incorporating the principles of agronomic management and farm planning. The choice of crop for each field must be based on an objective determination of gross income, input costs, field and crop rotation history. A crop rotation system for any given situation will be determined by:

(a) The objective and attitude of the farmer.
(b) The different enterprises on the farm and relevant commodity prices.
(c) The cash flow and economics of the cultivated crops.
(d) Agronomic management principles.
(e) Soil fertility status and acidity.
(f) Total rainfall and distribution in the growing season.
(g) Spectrum of weeds occurring in the fields.
(h) The rotation of Nitrogen fixing and Nitrogen dependent crops.
(i) Occurrence of plant disease and pests.
(j) The prevention in the build-up of soil-borne diseases.
(k) Available machinery and equipment.
(l) Livestock needs and fodder flow requirement.
(m) Market needs.

Benefits of a sustainable crop rotation system are reduced diseases, decreased weed burden, increased soil fertility and increased profit.

**Seed-bed preparation**

The soil is cultivated to produce favourable conditions for establishment of the wheat crop. Such conditions include soil in which sufficient water is stored for germination and early plant development. For summer wheat production which is under dryland, conventional tillage method is used (Fig. 9). For summer wheat production that is
under irrigation, immediately after harvesting the previous crop in May, the land is ploughed, disked and planted wheat. No fallow period is allowed, only two weeks in between is used for field operations.

There are three types of tillage systems that is normally used in wheat production i.e. conventional tillage, conservation tillage and direct seeding.
Conventional tillage (Fig. 9) is recommended for a wheat-on-wheat cropping system in which the risk of root disease is high and the risk of wind and water erosion minimal. The harvesting is done in December to January. As soon as soil conditions allow, disking of the soil is done. Ploughing is done between end of January to end of February in the drier areas and between mid February to the end of March in the wetter areas (Fig.10). The land should be left fallowed until June when planting commences. Shallow sweep cultivations (Fig.11) may be used to break the clots and level the seed-bed just before planting.

Conservation tillage (Fig. 12) is recommended in all areas where the risk of wind and water erosion is high, because of the low clay content of these soils. Harvesting is done in November to December. Disc harrow is used to control weeds. Deep tillage is done in March or April with a tine implement.

In order to seal the soil surface, use shallow tillage to prepare seed-bed and control weeds, thereafter plant wheat according to guidelines using a properly calibrated wheat planter (Fig. 13).
Figure 12: Conservation tillage

Figure 13: Wheat planter
Seed and sowing
The optimum time for sowing is determined by several factors, most important of which are temperature and moisture during growing season. Wheat needs chilling temperatures for vernalisation. Wheat is planted under dryland and irrigation conditions in the summer rainfall region, while in the winter rainfall region, it is planted under dryland conditions only. In the summer rainfall region, sowing commences from April to July, while in the winter growing season sowing commences in May to July.

Seeding rate ranges from 20 – 25 kg/ha and 90 – 120 kg/ha for dryland and irrigation, respectively. The inter-row and intra-row spacing are 40 – 50 cm and 7 – 15 cm respectively, when using a planter. Seed should be placed 5 cm deep. Always use treated seed for the control of soil-borne fungal diseases.

Plant population
The optimum plant population is that at which the cost of increasing the plant population is very close to that which gives maximum grain yield. Table 1 shows the plant population that has to be established in order to obtain a particular yield. Always calibrate the planter for the desired plant population (Fig. 13).

<table>
<thead>
<tr>
<th>Anticipated yield Potential (t/ha)</th>
<th>Target plant population</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plants/m²</td>
<td>Plants/m row</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>50</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>100</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>150</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td>200</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 1: PLANT POPULATION REQUIRED TO ACHIEVE YIELD POTENTIAL.

Cultivar choice
Cultivar choice is an important production decision and if correctly planned, could greatly contribute to reducing risk and optimizing yields. It is important for farmers to realise that there are cultivars for dryland and irrigation planting. Producers should also plant cultivars that are preferred by the millers (Table 2). Important factors determining cultivar choice are yield potential, grading and quality, diseases and pests, seed price, hectolitre mass, straw strength, aluminium tolerance, photoperiod and vernalisation, shatterproof and pre-harvest sprouting tolerance.

Important guidelines producers must consider in choosing a cultivar are:

(a) Plant a few different cultivars so as to spread risk, in terms of drought and diseases.
(b) Do not replace tried and tested cultivars within one season with a new and unknown cultivar.
(c) Cultivars should be chosen so as to adapt to specific yield potential conditions.
(d) Revise cultivar choice annually so as to adapt to changing circumstances and especially to consider new cultivars.

<table>
<thead>
<tr>
<th>Northern Dryland Production Areas</th>
<th>Cultivars preferred</th>
<th>Cultivars unwanted</th>
<th>Irrigation Areas</th>
<th>Cultivars preferred</th>
<th>Cultivars unwanted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belinda</td>
<td>PAN 3377</td>
<td>Adam Tas</td>
<td></td>
<td>Baviaans</td>
<td>Adam Tas</td>
</tr>
<tr>
<td>Betta DN</td>
<td>SST 107</td>
<td>Alpha</td>
<td></td>
<td>Buffels</td>
<td>Alpha</td>
</tr>
<tr>
<td>Caledon</td>
<td>SST 124</td>
<td>Gamtoos</td>
<td></td>
<td>CRN 826</td>
<td>Gamtoos</td>
</tr>
<tr>
<td>Carina</td>
<td>SST 308</td>
<td>Karee</td>
<td></td>
<td>Duzi</td>
<td>Karee</td>
</tr>
<tr>
<td>Carol</td>
<td>SST 319</td>
<td>Multilyn Z</td>
<td></td>
<td>Kariega</td>
<td>Multilyn Z</td>
</tr>
<tr>
<td>Elands</td>
<td>SST 322</td>
<td>Nantes</td>
<td></td>
<td>Krokodil</td>
<td>Nantes</td>
</tr>
<tr>
<td>Garies</td>
<td>SST 333</td>
<td>Palmiet</td>
<td></td>
<td>Marico</td>
<td>Palmiet</td>
</tr>
<tr>
<td>Hugenoot</td>
<td>SST 334</td>
<td>Scheepers 69</td>
<td></td>
<td>Olfants</td>
<td>Scheepers 69</td>
</tr>
<tr>
<td>Komati</td>
<td>SST 347</td>
<td>SST 38</td>
<td></td>
<td>PAN 3434</td>
<td>SST 38</td>
</tr>
<tr>
<td>Limpopo</td>
<td>SST 356</td>
<td>SST 44</td>
<td></td>
<td>SST 802</td>
<td>SST 44</td>
</tr>
<tr>
<td>Matlabas</td>
<td>SST 363</td>
<td>T4</td>
<td></td>
<td>SST 822</td>
<td>T4</td>
</tr>
<tr>
<td>Nossob</td>
<td>SST 366</td>
<td>Tugela</td>
<td></td>
<td>SST 825</td>
<td>Tugela</td>
</tr>
<tr>
<td>PAN 3118</td>
<td>SST 367</td>
<td>Tugela DN</td>
<td></td>
<td>SST 835</td>
<td>Tugela DN</td>
</tr>
<tr>
<td>PAN 3120</td>
<td>SST 399</td>
<td></td>
<td></td>
<td>SST 867</td>
<td></td>
</tr>
<tr>
<td>PAN 3122</td>
<td>SST 935</td>
<td></td>
<td></td>
<td>SST 874</td>
<td></td>
</tr>
<tr>
<td>PAN 3144</td>
<td>SST 936</td>
<td></td>
<td></td>
<td>SST 875</td>
<td></td>
</tr>
<tr>
<td>PAN 3161</td>
<td>SST 946</td>
<td></td>
<td></td>
<td>SST 876</td>
<td></td>
</tr>
<tr>
<td>PAN 3191</td>
<td>SST 954</td>
<td></td>
<td></td>
<td>SST 885</td>
<td></td>
</tr>
<tr>
<td>PAN 3211</td>
<td>SST 963</td>
<td></td>
<td></td>
<td>SST 886</td>
<td></td>
</tr>
<tr>
<td>PAN 3235</td>
<td>SST 964</td>
<td></td>
<td></td>
<td>Steenbras</td>
<td></td>
</tr>
<tr>
<td>PAN 3349</td>
<td>SST 966</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAN 3355</td>
<td>SST 972</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAN 3364</td>
<td>SST 983</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAN 3368</td>
<td>Tarka</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Fertiliser application**

The cost of fertiliser is a substantial proportion of the total production cost of wheat and the optimization of fertilising practices is therefore of the utmost importance.

The development of specifically adapted cultivars over the past few years has necessitated the planning of a fertilisation programme by the producer on an annual basis. As with cultivar choice, a fertilisation programme is planned on the basis of a specific yield potential or target yield. The following guidelines can be used as a reference to plan such a programme for a given situation.

Reliable soil analysis data is essential for planning an effective fertilisation programme. The regular sampling of lands to timeously identify problems, such as soil acidification, is absolutely essential.

**Soil sampling for analysis**

Soil is analyzed to determine its ability to supply the necessary plant nutrients to the crop concerned. Soil analyses are related to potential nutrient uptake, supplementation of plant nutrients through fertilisation and the target yield. From plant nutrient research programmes that take these factors into account, guidelines that will be valid in a given situation are laid down.

Therefore, to make the best possible use of these guidelines, it is essential that the soil samples that are interpreted are representative of the particular land. To achieve this, the following standard procedures are required when handling soil samples:

- (a) Homogeneous units that are also practical for crop production purposes must be sampled.
- (b) Homogeneity is determined by previous crop performance, topography and the soil depth, colour and texture.
- (c) A soil sample must represent a homogeneous unit of not more that 50 ha.
- (d) Homogeneous units must be numbered clearly and separately.
- (e) Problem/poor patches must be indicated and sampled separately.
- (f) When taking the sample, all foreign matter (grass, twigs, loose stones) must be removed at the sampling point. In the case of very rocky soils an estimate must be made of the rock percentage per volume.
- (g) Twenty to 40 samples must be taken at random over the entire area of each homogeneous unit of the land. Conspicuously poor patches, headlands, places were animals gather, etc, must be avoided.
- (h) The recommended depth for sampling the topsoil is about 200 mm, in other words the 0 – 200 mm portion of the topsoil is sampled.
- (i) Subsoil samples must be taken from the 200 – 600 mm layer of the profile for dryland cultivation, and at 300 – 600 and from 600 – 1 200 mm for irrigation.
- (j) If the land has been ploughed, random samples must be taken from the entire area. If the rows of the previous crop are still visible, the samples must be taken randomly between and in the rows.
(k) To compare results, sampling should be done at more or less the same time of the year every year, or during the same phase of the cultivation programme, but at least once every 3 years.

(l) The 20 – 40 samples from which the final sample is to be compiled must be collected in a clean bag. Farmers are warned against using salt bags, fertiliser bags or other contaminated containers. Clods must be crushed, foreign matter removed, and the soil must be mixed thoroughly. After spreading the soil in a thin layer, small scoops are taken evenly over the whole depth and area and placed in a clean plastic bag or carton. This final sample, representative of a homogeneous unit, must have a mass of 0.5 – 1.0 kg.

(m) Additional information about the properties of the soil, climate, production and fertilisation history should also be furnished, since recommendations cannot be based on soil analysis alone.

Soil acidity
One of the major wheat production problems in the summer rainfall region is the increased acidification of soils, especially in the higher rainfall areas. The negative effect of acid soil lies in the high level of free aluminium ions, when compared to other cation levels, in the soil. As a result, high concentrations of toxic aluminium are taken up by the wheat plant.

Although germination and establishment are not influenced by high Al$^{+3}$ concentrations in the soil, aluminium toxicity symptoms occur in the early plant development stages (usually September when warmer temperatures promote active growth). When the root system of the young plant is exposed to high aluminium levels, severe drought and nutrient stress symptoms appear and plant mortality may eventually occur. The symptoms of aluminium toxicity are clearly visible on the roots. The root tips become thickened, the lateral roots brittle and a brown discoloration take place. Inhibition of root growth limits the uptake of water and plant nutrients.

Guidelines
The pH (KCl) and soil texture is used to determine the lime requirements for wheat. Soil analysis for lime requirement purposes is essential when the soil pH (KCl) is below 4.5 pH (CaCl$_2$) below 5.0 or pH (H$_2$O) below 5.5. The table below shows the lime requirement (ton per hectare) for different pH values and clay percentages.

Because the ratio of aluminium to other cations in the soil is essential to the reaction of the plant, it is important to emphasize that lime is recommended if the percentage acid saturation is above 8% and/or if the pH (KCl) is below 4.5.
TABLE 3: LIME REQUIREMENTS (TON/HA) FOR DIFFERENT ACIDITY LEVELS AND CLAY CONTENT.

<table>
<thead>
<tr>
<th>% Clay</th>
<th>$\Delta$pH &gt;0.5</th>
<th>$\Delta$pH 0.5-0.4</th>
<th>$\Delta$pH 0.4-0.3</th>
<th>$\Delta$pH 0.3-0.2</th>
<th>$\Delta$pH 0.2-0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>3.9</td>
<td>3.0</td>
<td>2.2</td>
<td>1.4</td>
<td>0.5</td>
</tr>
<tr>
<td>10-15</td>
<td>4.1</td>
<td>3.3</td>
<td>2.5</td>
<td>1.6</td>
<td>0.8</td>
</tr>
<tr>
<td>15-20</td>
<td>4.4</td>
<td>3.5</td>
<td>2.7</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>20-25</td>
<td>4.6</td>
<td>3.8</td>
<td>2.9</td>
<td>2.1</td>
<td>1.3</td>
</tr>
<tr>
<td>25-30</td>
<td>4.8</td>
<td>4.0</td>
<td>3.2</td>
<td>2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>30-35</td>
<td>5.1</td>
<td>4.2</td>
<td>3.4</td>
<td>2.6</td>
<td>1.7</td>
</tr>
</tbody>
</table>

$\Delta$pH - Change in pH(KCl)
$\Delta$SV - Change in % acid saturation
Lime requirement = $\Delta$pH*8.32+0.0459*Clay-1.037

If the lime requirement exceeds 4 ton/ha, lime must be applied over two cropping seasons and not all at once. The equation from table 3 can also be used to calculate lime requirement, by inserting the desired change in pH and the clay content into the equation.

Lime requirement in the table is based on a lime source with a CCE (Resin) of 75.3. If the lime source has a CCE (Resin) value higher or lower than 75.3 the following adaptations must be made for a soil with a lime requirement of 3.5 ton/ha.

Suppose a CCE (Resin) of 90%, then the actual lime requirement will be as follows:

$$75.3/90 = 0.84$$
$$3.5 \times 0.84 = 2.93 \text{ ton lime/ha, thus } 3 \text{ ton/ha}$$

Suppose a CCE (Resin) of 60%, then the actual lime requirement will be:

$$75.3/60 = 1.26$$
$$3.5 \times 1.26 = 4.4 \text{ ton lime/ha thus } 4.5 \text{ ton/ha}$$

Type of liming material
It is essential that the lime source (calcitic or dolomitic) be selected correctly. The type of lime to be used is determined by the Ca:Mg ratio and the Mg$^{2+}$ content of the soil. If the Ca:Mg ratio is higher than 10:1, dolomitic lime is recommended. When the Ca:Mg ratio is lower than 10:1 the choice of lime source is determined by the Mg$^{2+}$ content of the soil. If it is higher than 40 mg/kg (ppm.), calcitic lime is recommended, while dolomitic lime is used when the Mg$^{2+}$ content of the soil is lower than 40 mg/kg.
The application of lime
Liming material must comply with certain specifications of fineness and reactivity for the effective neutralizing of acid soils. Dolomitic agricultural lime must contain more than 20% magnesium carbonate (MgCO\(_3\)) and calcitic agricultural lime more than 70% calcium carbonate (CaCO\(_3\)). Lime must have a fineness of less than 250 micron.

It is essential that lime be applied three to four months before planting. When dry soils are limed only a small change in the pH values will be obtained. Soil texture (which is the most important factor), nitrogen fertilisation and the quantity and quality of lime applied, will determine how often lime has to be re-applied. Acidification is more rapid in light textured soils than in the clayey soils because of their differences in buffer capacity. Light textured soils have lower lime requirements to attain certain soil pH levels.

It is essential to remember that a good reaction will only be obtained when the lime is well mixed with the soil. The lime particles must come into close contact with the silt and clay particles to displace the hydrogen and aluminium ions. Lime has to be mixed into the soil with an offset or disc, and then ploughed in to a depth of 200 mm to 400 mm.

Cultivar choice as a remedy
In association with the liming programme, cultivars with good aluminium tolerance can also be used to limit yield losses caused by acid soils. Considerable variation in genetic (cultivar) tolerance to aluminium toxicity exists. Cultivars can be divided into three classes of aluminium tolerance:

(a) Good tolerance
(b) Reasonable tolerance
(c) Poor tolerance

<table>
<thead>
<tr>
<th>Good tolerance</th>
<th>Reasonable tolerance</th>
<th>Poor tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAN 3349</td>
<td>Gariep</td>
<td>Betta-DN</td>
</tr>
<tr>
<td>PAN 3377</td>
<td>Caledon</td>
<td>Limpopo</td>
</tr>
<tr>
<td>SST 966</td>
<td>Elands</td>
<td>PAN 3235</td>
</tr>
<tr>
<td>PAN 3120</td>
<td>PAN 3191</td>
<td>SST 399</td>
</tr>
<tr>
<td>PAN 3118</td>
<td></td>
<td>PAN 3364</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Komati</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SST 322</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SST 334</td>
</tr>
</tbody>
</table>

TABLE 4: CULTIVARS IN DIFFERENT CLASSES OF ALUMINIUM TOLERANCE.
It is important to keep in mind that cultivar choice is not only made on the basis of aluminium tolerance. Grain quality still remains one of the most important focus points of cultivar choice. Cultivar choice in terms of aluminium tolerance is only a short term solution with a certain amount of risk attached. Cultivar choice could effectively be used to overcome the acidity problem during the neutralisation period. Liming programmes will not only lower the production risk, but also sustain the soil for future generations.

Wheat plant requires adequate nutrients to grow and produce high yield of good quality. Nutrients critical for the growth and development of wheat are nitrogen, phosphorus and potassium. However, high levels of nitrogen cause severe lodging in tall cultivars; while low levels cause yellowing of the leaves and stunted growth. Nitrogen is responsible for the deep green colour of the leaves. Phosphorus in inadequate amount shows purple leaves and retarded root development. It is responsible for root proliferation.

Nitrogen required by wheat per hectare is 40 – 60 kg and 160 – 180 kg under dryland and irrigation conditions respectively. Phosphorus requirement is 12 – 15 kg P/ha. It is advisable to take soil samples every three years and send it to a soil laboratory for determination of various nutrients in the soil obtained from your field. The results will show as to how much nutrients have to be supplemented to meet the crop requirement. Tables 5 – 8 below depict the amount in the soil and amount to be applied for phosphorus and potassium. For application of nitrogen, yield target is used to determine nitrogen to be applied. Since nitrogen is subject to leaching, immobilization and volatization, it is suggested that it must be applied in two splits; one as basal dressing and the other as top-dressing particularly where irrigation is practised. In dryland conditions, no split application is necessary. Table 5 shows that if the farmer is in the area that has the potential to produce 2.5 t/ha wheat, 45 – 50 kg N/ha has to be applied.

<table>
<thead>
<tr>
<th>Target yield (ton/ha)</th>
<th>N fertilisation (kg N/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>10</td>
</tr>
<tr>
<td>1.5</td>
<td>15-20</td>
</tr>
<tr>
<td>2.0</td>
<td>25-30</td>
</tr>
<tr>
<td>2.5</td>
<td>45-50</td>
</tr>
<tr>
<td>3.0</td>
<td>55</td>
</tr>
<tr>
<td>3.5</td>
<td>65+</td>
</tr>
</tbody>
</table>

TABLE 5: NITROGEN FERTILISATION ACCORDING TO TARGET YIELD IN THE SUMMER RAINFALL AREA.
Similarly, Table 6 is used to determine the amount of nitrogen that has to be applied in a particular location that is under irrigation. Under irrigation, yield is doubled compared to dryland, hence the amount of nitrogen is so high. Where the farmer is targeting the yield of 6 – 7 t/ha, 160 – 180 kg N/ha should be applied.

**TABLE 6: NITROGEN FERTILISATION (KG N/HA) ACCORDING TO TARGET YIELD UNDER IRRIGATION.**

<table>
<thead>
<tr>
<th>Target yield (ton/ha)</th>
<th>Nitrogen (kg N/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>80-130</td>
</tr>
<tr>
<td>5-6</td>
<td>130-160</td>
</tr>
<tr>
<td>6-7</td>
<td>160-180</td>
</tr>
<tr>
<td>7-8</td>
<td>180-200</td>
</tr>
<tr>
<td>8+</td>
<td>200+</td>
</tr>
</tbody>
</table>

The amount of phosphorus that has to be applied is dependent on phosphorus that is already in the soil and target yield. If after soil analysis, the results show that the amount of phosphorus in the soil is between 5 – 18 mg/kg and your target yield is 2.5 tons/ha, 15 kg/ha of phosphorus has to be applied in order to meet the target yield. Tables 7 and 8 below are used for phosphorus application for a target yield when the phosphorus status is known, under dryland and irrigation.

**TABLE 7: PHOSPHORUS FERTILISATION (KG/HA P) ACCORDING TO TARGET YIELD UNDER DRYLAND CONDITIONS AND SOIL STATUS ACCORDING TO THE BRAY 1 ANALYSIS METHOD.**

<table>
<thead>
<tr>
<th>Target yield (ton/ha)</th>
<th>Soil phosphorus status (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 5*</td>
</tr>
<tr>
<td></td>
<td>5-18*</td>
</tr>
<tr>
<td></td>
<td>19-30</td>
</tr>
<tr>
<td></td>
<td>&gt;30</td>
</tr>
<tr>
<td>1.0</td>
<td>6</td>
</tr>
<tr>
<td>1.5</td>
<td>9</td>
</tr>
<tr>
<td>2.0</td>
<td>12</td>
</tr>
<tr>
<td>2.5+</td>
<td>18</td>
</tr>
</tbody>
</table>

**TABLE 8: PHOSPHORUS FERTILISATION (KG/HA P) ACCORDING TO TARGET YIELD UNDER IRRIGATION AND SOIL PHOSPHOROUS STATUS ACCORDING TO BRAY 1 ANALYSIS METHOD.**

<table>
<thead>
<tr>
<th>Target yield (ton/ha)</th>
<th>Soil phosphorus status (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>10-18</td>
</tr>
<tr>
<td></td>
<td>19-30</td>
</tr>
<tr>
<td></td>
<td>&gt;30</td>
</tr>
<tr>
<td>4-5</td>
<td>36</td>
</tr>
<tr>
<td>5-6</td>
<td>44</td>
</tr>
<tr>
<td>6-7</td>
<td>52</td>
</tr>
<tr>
<td>7+</td>
<td>&gt;56</td>
</tr>
</tbody>
</table>
The amount of potassium that has to be applied is dependent on potassium that is already in the soil and target yield. If after soil analysis, the results show that the amount of potassium in the soil is between 61 – 80 mg/kg and your target yield is 2 ton/ha, 20 kg/ha of potassium has to be applied in order to meet the target yield under dryland conditions (Table 9). Table 10 is used for K application together with target yield under irrigation.

**TABLE 9: GUIDELINES FOR POTASSIUM FERTILISATION (KG /HA K) UNDER DRYLAND CONDITIONS ACCORDING TO SOIL POTASSIUM LEVELS AND TARGET YIELDS.**

<table>
<thead>
<tr>
<th>Target yield (ton/ha)</th>
<th>&lt;60</th>
<th>61-80</th>
<th>81-120*</th>
<th>120+</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>2-3</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>3+</td>
<td>40</td>
<td>25</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

*Soil with > 35% clay (Soil with < 35% clay content, no potassium recommended, but potassium applications may be done for maintenance of soil K values.)*

**TABLE 10: GUIDELINES FOR POTASSIUM FERTILISATION (KG /HA K) UNDER IRRIGATION ACCORDING TO SOIL POTASSIUM LEVELS AND TARGET YIELDS.**

<table>
<thead>
<tr>
<th>Target yield (ton/ha)</th>
<th>&lt;60</th>
<th>61-80</th>
<th>81-120*</th>
<th>120+</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>50</td>
<td>25</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>5-6</td>
<td>60</td>
<td>30</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>6-7</td>
<td>70</td>
<td>35</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>7+</td>
<td>80</td>
<td>40</td>
<td>40</td>
<td>0</td>
</tr>
</tbody>
</table>

* *Soil with > 35% clay (Soil with < 35% clay content, no potassium is recommended)*
Crop water use at different stages of growth
From studies by the University of the Free State, a table was compiled that indicates the general water requirement of wheat under irrigation based on a water use efficiency of 10 kg grain yield per mm water applied (Table 11). There are also certain growth stages that are more critical in efficient water management. These growth stages and components most affected are listed in order of importance:

- **Grain filling**: Yield, hectolitre mass and kernel weight.
- **Ear emergence to flowering**: Decrease in kernel number and grain protein.
- **Flag leaf**: Decreased kernel number per ear, grain protein and yield.
- **Stem elongation**: Development of florets in developing ears is affected and decrease in kernel differentiation (amount per ear).
- **Tillering**: Development of additional tillers, secondary root development and yield potential development are affected.

**TABLE 11: WATER REQUIREMENT OF WHEAT AT CERTAIN GROWTH STAGES FOR A YIELD OF 7 T/HA.**

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>mm</th>
<th>water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant to emergence</td>
<td>58</td>
<td>8.3</td>
</tr>
<tr>
<td>Tillering to stem elongation</td>
<td>67</td>
<td>9.6</td>
</tr>
<tr>
<td>Stem elongation to flag leaf</td>
<td>105</td>
<td>15.0</td>
</tr>
<tr>
<td>Flag leaf to flowering</td>
<td>211</td>
<td>30.1</td>
</tr>
<tr>
<td>Grain filling</td>
<td>173</td>
<td>24.7</td>
</tr>
<tr>
<td>Maturity</td>
<td>86</td>
<td>12.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>700</td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
6. Crop protection

Pest control
Summer rainfall areas

A variety of insects with different feeding habits are found on wheat and not all these pests are equally injurious. Therefore the decision to control should be made individually for each pest using the guidelines provided and the particular control measure should be chosen to give the best result in both economic and environmental terms. The correct identification of pests is of utmost importance to ensure that the appropriate control measure is followed. A “Field guide for the identification of wheat insects in SA” is available from ARC-Small Grain Institute at a cost of R50 (+ R6 postage). This full colour guide contains a short description and photograph of each insect and includes both pests and beneficial insects. A pamphlet containing information on the registered insecticides is also included. It is helpful to make use of a magnifying glass when identifying wheat insects, as most of them are quite small. Goddy Prinsloo, Justin Hatting, Vicki Tolmay or Astrid Jankielsohn can be contacted for more information. Guidelines for the control of insect pests are discussed below.

Aphids

Five aphid species are commonly found on wheat in the summer rainfall production areas in South Africa. The Russian wheat aphid (*Diuraphis noxia*) is the most important with outbreaks occurring annually, while the other aphids namely greenbug (*Schizaphis graminum*), bird-cherry oat aphid (*Rhopalosiphum padi*), brown ear aphid also called English grain aphid (*Sitobion avenae*) and the rose grain aphid (*Metopolophium dirhodum*) occur sporadically. Generally Russian wheat aphid and greenbug occur in dryer, low potential circumstances while bird-cherry oat aphid, brown ear aphid and rose grain aphid occur in wetter, high potential environments.

a) Russian wheat aphid (*Diuraphis noxia*)

*D. noxia* is a small (<2.0 mm), spindle shaped, pale yellow-green to grey-green aphid with extremely short antennae and a “double tail” (Figure 14). Until 2005 only one biotype of the aphid was prevalent in the Free State Province namely RWASA1, however, a more damaging Russian wheat aphid was identified during the 2005 season and cultivars resistant to the original RWASA1 are damaged by the new aphid. Host plant resistance has been the best control option for Russian wheat aphid for the past 12 years. Cultivars with resistance to RWASA1 are not as badly damaged by the new biotype as susceptible cultivars and are therefore still recommended. It is not possible to distinguish the biotypes visually, however damage symptoms can easily
be distinguished from the resistance reaction. Young plants showing a susceptible reaction become prostrate and the leaves roll tightly closed. On more mature plants susceptible symptoms include longitudinal, white or pale yellow stripes, which can turn purple when cold conditions prevail, tightly rolled leaves and trapped heads. In contrast, only small white or yellow splotched and spots occur on the leaves of plants showing resistance and the leaves do not roll tightly closed as in the case of susceptible plants. Producers should scout fields regularly and be aware that it may be necessary to apply insecticides if aphid populations increase.

Figure 14: Russian wheat aphid

Wheat is most damaged by Russian wheat aphid during the period between the emergence of the flag leaf (GS 14) and the awn (GS 18). Chemical treatment at GS 12 will ensure that the upper two leaves are protected from aphid infestation and this will reduce yield loss. Spraying before GS 12 is recommended only in cases of severe infestation > 30%, something which may occur on wheat planted during spring in the Eastern Free State or under very dry conditions in the Western Free State. Re-infestation of this wheat may occur during the susceptible period necessitating an additional spray, while some damage may already have occurred when spraying takes place after GS 12. Infestation levels at various yield potentials, which necessitate spraying, are given in Table 12. Seed treatments and soil systemic insecticides are available for control of aphid populations and control for up to 100 days after planting is possible.
Determining the percentage aphid infestation in a field

By determining the percentage infestation of a field, a farmer will be able to decide whether aphids must be controlled by chemical means. If the percentage infestation of a field is equal or higher than the recommendation for that specific field, the eventual yield will, due to Russian aphid damage, not reach the optimum yield potential. Steps for determining the percentage infestation in a field is as follows:

(a) Decide beforehand how many steps will be used as a standard and which foot will be the marker foot.
(b) Walk into the filed for a short distance and then start to count off the number of steps that was decided on. On the specific number of steps ten plants closest to the front of the marker foot is inspected for aphids. The number of plants infested out of ten is then recorded.

This procedure is now repeated throughout the field for ten times or more. The scouting route must represent the whole field as aphid infestations usually occur in patches. The largest number as possible of repetitions should be scouted as it will increase the accuracy of the percentage infestation.

<table>
<thead>
<tr>
<th>Yield potential (ton ha⁻¹)</th>
<th>Infestation level at GS 12 (% plants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 - 2.5</td>
<td>7</td>
</tr>
<tr>
<td>1.5 - 2.0</td>
<td>10</td>
</tr>
<tr>
<td>1.0 - 1.5</td>
<td>14</td>
</tr>
</tbody>
</table>

b) Other aphids

The Oat aphid, English grain aphid and rose-grain aphid are sporadic pests of wheat in the summer rainfall area. These aphids prefer thick plant densities with damp conditions like conditions in irrigated fields, but will also be present in wet years in dryland fields.

The oat aphid has a dark green pear shaped body with a red coloured area between the siphunculi on the rear end of the aphid (Figure 15a). A green and brown form of the English grain aphid (Figure 15b) could be found. Long black siphunculi on the rear end is the most outstanding characteristic of this aphid. The rose-grain aphid is pale yellow in colour with a dark green longitudinal stripe on the back (Figure 15c). The siphunculi of this aphid is the same colour as the body.
The feeding damage measurement of 70% ears infested with 5 – 10 aphids per ear could be used for the control of the aphids. Trials to determine more refined measure are progressing in the winter rainfall areas. Be sure that chemical control is applied correctly when necessary – read the label and do the application accordingly too. Be careful to apply the correct dosage, a wrong dosage could cause the necessity of another application which have financial implications and cause a risk of resistance development in aphids. Unnecessary applications should be reduced to a minimum, because it is also killing the natural enemies, which is important in the control of aphids. When the environment around the fields progress in ecological balance, an increase in natural enemies could occur, which will control the aphids and reduce the control costs.

Other insect pests
The following insects are considered sporadic, secondary pests of small grains in the summer rainfall region:

a) Brown wheat mite (*Petrobia latens*)
These mites are small, dark brown with a slightly oval body: the first pair of forelegs being notably longer than the others. Scouting should be conducted during the day as mites spend the night and times when it is hot and windy beneath soil clots. Eggs are laid on the underside of clots and two types of eggs are laid. Red active eggs are laid, that may hatch after within a few days and white dormant eggs that may remain in the soil for a period of 1 year. After hatching, dry conditions will promote population increases with affected plants showing mottled leaves due to sap-feeding activity. Under severe infestations, leaves may turn yellow or bronze resulting in yellow or brown patches appearing in the field. Chemical control can be considered under
such conditions. On the other hand, brown wheat mite damage is more pronounced when plants are under stress and these conditions are generally inhibitive for the uptake and translocation of systemic insecticides. Producers should also take note that rain showers of 12 mm or more can effectively reduce mite populations, thereby negating the need for chemical intervention.

b) False wireworm (*Somaticus* sp., *Gonocephalium* sp.)
The false wireworm belongs to the family Tenebrionidae and is the larval stage of large dark coloured beetles with long legs, often seen running on the soil surface and hiding under plant litter. The larval is the most damaging stage feeding on seed, roots and seedling stems at or just below the soil surface. Adult beetle may damage emerging seedlings. The larvae can grow to 20 mm in length and are smooth and golden to dark brown in colour. Cultural practices aimed at targeting the larval stage in the soil can help reduce populations, as adult beetles cannot fly and each field therefore has a resident population fluctuating in numbers from year to year. Seed treatments can also be used with best effect where seedlings grow actively in moist soil.

c) Bollworm (*Helicoverpa armigera*)
The adult moths are light brown to grey with a wingspan of about 20 mm. The moths fly at dawn and dusk laying their eggs directly on the plant. Young larvae of early season generations initially feed on the chlorophyll of leaves, later migrating into the awn to feed on the developing kernels. Moths of later generations deposit their eggs directly on the awn. Final instar larvae can vary from bright green to brown and have a characteristic lateral white stripe on either side. The larvae can reach up to 40 mm in length and can cause considerable damage, especially in terms of quality loss and subsequent down-grading of the consignment. The presence of bollworm is generally noticed only once the larvae have reached the mid-instar stage inside the awns. Producers should scout their fields in order to detect the younger larvae, as the older, more mature larvae, are generally less susceptible to insecticides and obviously cause more damage compared with the small larvae. Under dry land conditions, chemical intervention can be considered when 3 – 4 larvae are present per metre row. A slightly higher threshold of 6 – 7 larvae per metre is applicable under irrigated conditions with higher seeding density. However, producers should take care in applying the correct dose of registered insecticide under weather conditions conducive to insect control.

d) Black maize beetle (*Heteronychus arator*)
The adult beetle is black, about 12 – 15 mm in length and capable of extended light. Females lay about 7 – 10 eggs in the soil and the larvae develop through three instars followed by a pupal stage. The beetles are the most damaging stage while their
larvae survive mostly on organic material in the soil. Adults chew at the base of the seedling stem resulting in a reduced stand. Given the migrating nature of the adult stage, seed treatments with a registered insecticide is a pre-plant approach toward control of adult beetles.

e) Leafhoppers and maize streak virus
Maize streak virus spreading, which could be transferred from infested maize and some grasses, is mainly dependant on the pest status of the leafhopper *Cicadulina mbila* on wheat and some grasses. Early planted wheat in the close vicinity of maize fields is the most vulnerable. When young wheat plants become infested, they become stunted and curled leaves shows thin white longitudinal stripes. No chemicals are registered for the control of leafhoppers on wheat. Infestation could be prevented by later planting dates away from maize fields.

Winter rainfall areas and irrigation
Aphids
Aphid species, causing problems in the winter rainfall area are mainly oat aphid, English grain aphid and rose grain aphid. Russian wheat aphid, which is the most severe wheat aphid in South Africa, is a sporadic pest in this area. The former aphids prefers thick plant densities with damp conditions which is typical of the winter rainfall area as well as irrigated fields. During dry conditions in this area aphid numbers are low, with exception of Russian wheat aphid, which prefers dry conditions.

The oat aphid has a dark green pear shaped body with a red coloured area between the siphunculi on the rear end of the aphid (Figure 16a). A green and brown form of the English grain aphid (Figure 16b) could be found. Long black siphunculi on the rear end is the most outstanding characteristic of this aphid. The rose-grain aphid is pale yellow in colour with a dark green longitudinal stripe on the back (Figure 16c). The siphunculi of this aphid is the same colour as the body.
Oat aphid prefers to feed on the stems of plants, and when present early in the season, they are feeding on the stems close to soil surface. At a later stage they are feeding on the stem beneath the ear and could move into the ear. English grain and rose grain aphids are feeding on the underside of the upper leafs and after heading, English grain aphid will move into the ear. These aphids are not regarded as highly damaging. The aphids are known to be present on the wheat plants at the same time, and the damaging potential of each species could therefore not be determined easily. From a spry trial in the southern Cape the presence of the different aphids over time was determined (Figure 17). English grain aphid was the most abundant.

Chemical control can be applied when 70% ears are infested with 5 – 10 aphids per ear for the control of the aphids. Trials to determine more refined measures are progressing in the winter rainfall areas. Be sure that chemical control are applied correctly when necessary – read the label and do the application according too. Be careful to apply the correct dosage, a wrong dosage could cause the necessity of another application which have financial implications and cause a risk of resistance development in aphids. Unnecessary applications should be reduced to a minimum, because it is also killing the natural enemies, which is important in the control of aphids. When the environment around the fields progress in ecological balance, an increase in natural enemies could occur, which will control the aphids, and reduce the control costs.
Other insect pests

a) Bollworm (*Helicoverpa armigera*)

The adult moths are light brown to grey with a wingspan of about 20 mm. The moths fly at dawn and dusk laying their eggs directly on the plant. Young larvae of early season generations initially feed on the chlorophyll of leaves, later migrating into the awn to feed on the developing kernels. Moths of later generations deposit their eggs directly on the awn. Final instar larvae can vary from bright green to brown and have a characteristic lateral white stripe on either side. The larva can reach up to 40 mm in length and can cause considerable damage, especially in terms of quality loss and subsequent downgrading of the consignment. The presence of bollworm is generally noticed only once the larvae have reached the mid-instar stage inside the awns. Producers should scout their fields in order to detect the younger larvae, as the older, more mature larvae, are generally less susceptible to insecticides and obviously cause more damage compared with the small larvae. Chemical control can be considered when 5 – 8 larvae are present per square meter. However, producers should take care in applying the correct dose of registered insecticide under weather conditions conducive to insect control.

b) Grain chinch bug (*Macchaidemus diplopterus*), or Grain stinkbug

These narrow elongated bugs are sap feeders and measure 4 – 5 mm in length. The eggs are laid in rows of up to 150 on the leaf sheaths and the young wingless nymphs with yellow to orange coloration appear during spring. Both nymphs and adults feed by sucking sap from the plant leading to slightly yellow, withered appearance. Sap may also be sucked from the seed. Damage is more pronounced under warm, dry conditions as stressed plants have less ability to tolerate/recover from chinch bug damage. During early summer adults migrate to alternate host plants where they over-summer before re-infesting the wheat crop during winter. Although no insecticides are registered against this insect on wheat, the closely related false chinch bug *Nysius natalensis* does have systemic insecticides registered. However, no threshold values are currently available for either species on wheat.

c) Grain slug (*Lema erythrodera*)

Although the name implies otherwise, this is not a slug but the larva of a metallic green beetle. The adult measures about 5 mm in length and occurs on cereals form June onwards. Eggs are laid in groups of 2 – 5 in rows along the main vein of the leaf. The larvae are pale, but soon cover their bodies with a blackish substance giving them a slug-like appearance. The larvae feed between the veins resulting in white longitudinal stripes developing on damaged leaves. Currently, no insecticides are registered on wheat.
d) Black sand mite or red-legged earth mite (*Halotydeus destructor*)
These are small black mites, 0.5 mm in length with red legs, first appearing after good autumn or winter rains. The mites feed on plant sap resulting in silvery white scars adjacent to the main vein of especially older leaves. High infestations could lead to dying off of small plants. The mites oversummer in eggs retained by the female inside her body until after her death. A single systemic insecticide is registered although no threshold value is available.

**Disease control (All regions)**

**Root diseases**

**Take-all**

Take-all (vrotpootjie) of wheat is caused by the fungal pathogen *Gaeumannomyces graminis var. tritici*, otherwise commonly known as Ggt. This disease can lead to yield losses of up to 72% if not controlled from the onset. A typical take-all infestation is characterized by the appearance of patches of bleached spikes (white-heads) before ripening. These spikes produce stunted, shriveled seeds and may even be sterile (produce no seed). In addition to bleached white-heads, a black discolouration of the root system and basal stems can be observed (Fig. 18). Stunting and reduced tillering of the wheat plant is frequently noted earlier during the growth cycle of the plant. A useful tip to detect the disease in a field is to attempt to pull a plant out of the ground. An infected plant will be easily pulled from the ground and will exhibit the typical blackened, damaged roots.

Several factors have been found to promote take-all incidence. These factors include sandy, alkaline, infertile and poorly drained soils, higher than recommended seeding densities, soils with a high organic matter content as well as manganese and nitrogen deficiencies. The most significant factor that is able to promote disease incidence however, is the monoculture of wheat on a field that either previously sustained an alternate host (e.g., soybean or lucerne) of the pathogen, or a field in which the disease was prevalent during a previous season. Take-all can be effectively managed by applying both chemical and cultural control measures. To date, Latitude® is the only fungicidal seed treatment that is registered for use against take-all in South Africa. It must be understood that the use of Latitude does not completely eliminate the disease. Instead, it ensures that when disease does occur, the roots are strong enough to withstand severe infection, which enables the plant to yield closer to its full potential. With regard to cultural control strategies, crop rotation using a non-host crop (sunflower, potatoes, oats) serves to best curb take-all. The application of ammonium forms of nitrogen has also been shown to improve plant resistance to take-all. This in combination with potassium chloride or other chlorine containing fertilisers should be used.
Crown rot occurs when the stem bases of mature plants are infected by numerous fungal pathogens of the genus Fusarium. The symptoms of this disease usually become most evident at flowering or after a period of long moisture stress, when either the entire plant or plant parts suddenly die off. As a result, the disease occurs wherever wheat is cultivated under dryland conditions, particularly in the central and Western Free State and in the Swartland and Humansdorp areas of the Western Cape. Symptomology is similar to that of take-all infestations with respect to the development of sterile white-heads, however certain distinctive features can be used to distinguish between crown-rot from take-all. These include a reddish-brown discolouration of the basal stem (black with take-all infections) and stem cavities that are filled with white/reddish fungal hyphae (Fig.19). There are no fungicides that are currently registered against crown rot in South Africa. All cultivars are susceptible, although a few are more tolerant to the disease than others. The application of a fallow system and the prevention of soil compaction are important in being able to manage the disease. Higher than recommended planting densities and excessive nitrogen applications should also be avoided in low rainfall regions.
**Foliar diseases**

**Yellow rust or stripe rust**

*Puccinia striiformis* f.sp. *tritici* is an obligate parasite and can only grow in living host material. This pathogen can infect wheat, barley, triticale, rye and some other grass species. Symptoms of stripe rust are usually systemic, bright yellowish to orange pustules that appear in linear rows on the leaf (Fig. 20). With severe infections pustules can also occur on the stem or in the spikelets (in the head). Stripe rust appears early in spring and requires temperatures that range from 10 – 20°C with intermittent rain and/or dew. Free water is needed for germination and infection. During hot and dry periods, sporulation ceases but will often restart with cool moist conditions. Various triazole-based fungicides are registered against this disease. Chemical control should be applied after the correct identification of the disease and when conditions are favourable for disease incidence and spread. If an epidemic occurs on susceptible cultivars, the correct timing of spraying is very important so as to protect the plant during the grain filling period. Severe infections can cause yield losses by reducing the number of kernels per spike and kernel quality.

![Figure 20: Early and late symptoms of yellow rust](image)

**Leaf Rust**

Also known as brown rust. This disease is caused by *Puccinia recondita* f.sp. *tritici*. The circular or elliptical pustules are orange-red to orange-brown in colour and occur on the leaf surfaces (Fig. 21). Leaf rust infects small grains as well as different grass species. The pustules are smaller than those of stem rust. Initially the leaves are green but as the pustules form, the leaves turn necrotic and brown in colour. Masses of black teliospores may appear on mature plants when environmental conditions are not favourable. Correct timing of spraying is imperative so as to protect the plant during the grain filling period. Severe infections can lead to losses/reductions in yield as well as in number of kernels per spike. Kernel quality is also compromised when disease is severe.
Stem rust
Stem rust caused by *Puccinia graminis*. f.sp. *tritici*, also known as black rust, is an obliged parasite and can only grow on living host material. Wheat, barley, rye and some grass species are also susceptible to stem rust. Symptoms include raised oval-shaped, dark reddish-brown pustules that will occur on the stems of the plants (Fig. 22). With severe infections, the leaves, leaf sheaths, glumes, awns and even seed of susceptible cultivars can become infected. Optimum temperatures for spore germination range between 15 – 24°C. Stem rust is more prevalent later in the growing season with hot and humid weather further promoting disease incidence. Early infections will reduce the amount of tillers and result in losses in grain weight and quality. Under favourable conditions, complete crop losses can occur.
Glume blotch
Glume blotch of wheat is caused by the seed-borne fungus, *Septoria nodorum*, and affects both glumes and foliage. This disease mainly occurs on late plantings in the Eastern Free State and KwaZulu-Natal and spores can remain viable on stubble for up to 12 months. Conditions conducive to the development of the disease include leaf wetness of up to 7 hours, average temperatures of between 15 – 25°C and relatively high humidity.

Symptoms associated with glume blotch differ from cultivar to cultivar depending on the susceptibility of the plant. Lens-shaped lesions are common on older, more susceptible cultivars. These lesions appear brown with blackened centres and are surrounded by large areas of necrotic tissue. On more resistant cultivars, lesions are smaller and surrounded by smaller regions of necrotic tissue. Small, black fruiting bodies (pycnidia) can also be found on the glume tissue of an infected ear. This disease can be efficiently controlled using resistant cultivars. A wide range of fungicides is also available against the disease, but these must only be applied after positive identification of the disease. Glume blotch becomes most destructive when infection occurs from the flag leaf to flowering stage of development, hence it is imperative that the plant is protected during this period. Aside from chemical control, cultural practises, such as the incorporation or burning of stubble, may control the disease. However, crop rotation remains the best option for control.

Powdery Mildew
Powdery mildew caused by *Erysiphe graminis* f. sp. *tritici* occurs in humid conditions and infects wheat, barley, oats, rye and a number of grasses. Symptoms of powdery mildew include white to grey cottony colonies on all aerial portions of the plant. Powdery mildew is usually more prevalent on the upper surface of the lower leaves (Fig. 23) but this disease can also spread to the heads with severe infections. Tiny black fruiting bodies are formed on the older lesions on the plants and these fruiting bodies act as survival structures. Powdery mildew is favoured by cool, cloudy and humid conditions as well as a dense stand of plants. Optimum temperatures for the development of this disease range between 15 – 22°C. As a result of infection, plant development becomes impaired from heading right through to seed filling.
Loose smut
This disease, caused by *Ustilago tritici*, occurs wherever wheat is grown. Typical symptoms of this disease can only be seen after head emergence. Infected as well as healthy heads emerge at the same time. On infected heads, masses of dark brown spores will replace the grain. These spores will be blown away and only the bare rachis will remain. Spores will infect the healthy heads, become dormant and in the following year this disease will re-emerge. Disease development is favoured by cool, humid conditions that will prolong the flowering period of the plant. To prevent loose smut, it is recommended that chemical seed treatments be used. In addition, it is advised that producers make use of certified seed only.

Stinking smut
This disease caused by *Tilletia* species, is commonly found on wheat, barley and certain grass species. Typical symptoms can be seen after heading. Spikes are darker in colour, differ in height and abnormalities of the spikes occur. These infected spikes take longer to mature. Bunt balls stay enclosed in the seed coat until harvesting and are greyish brown and spherical in shape. When these spore balls are crushed, black powdery spores are released and they emit a strong fishy odour. During harvesting, spores are dispersed and further contaminate the grain and soil. To prevent stinking smut, make use of certified seed or alternatively, apply chemical seed treatments prior to planting.
Diseases more prevalent under irrigation

Maize streak virus

Maize streak virus (MSV) leads to a condition known as wheat streak or wheat stunt. This disease is transmitted by leafhoppers that contain the virus within their systems and pass it through to the plant during feeding. Leafhopper numbers are considerably higher where the weather is warmer, hence disease levels are higher in these regions. Problem areas include regions of the Northern Province (Limpopo), Vaalharts-region and KwaZulu-Natal. Typical symptoms of MSV include stunted plants with fine, narrow, yellow stripes along the length of the leaf (Fig. 24). These stripes appear to begin at the tip of the leaf and work their way downwards towards the base. Ears also appear shrivelled and do not emerge well. The use of resistant cultivars serves as the most sustainable control option against this disease.

![Figure 24: Maize streak virus](image)

Fusarium head blight

_Fusarium graminearum_ is the causal organism for fusarium head blight or scab. Typical symptoms include the premature bleaching of one or all the spikelets on an ear. Spikelets quickly lose chlorophyll and become pale in colour (Fig. 25). Above the point of infection spikelets are usually sterile or seed are shrivelled, small and pinkish-white in colour. Favourable conditions include temperatures between 16 – 36°C, as well as high relative humidity. Due to the production of mycotoxins such as DON, NIV and ZEA, scab can cause additional loss for agriculture. The disease is especially prevalent under central-pivot irrigation where “wheat on wheat” or “wheat on maize” crop rotation systems are followed. The most effective way to control this disease is through crop rotation with non-host crops, as well as the destruction of wheat and maize residues. Chemical seed treatments can also be used as a preventative measure. The use of fungicides is often impractical because the wheat has to be sprayed during flowering stage and often flowering is staggered, but no chemicals are registered in South Africa against this disease.
Karnal Bunt
Karnal bunt (KB), caused by the smut fungus *Tilletia indica* var. Mitra, is currently known to occur in the Douglas/Prieska irrigation area. KB is regarded as a quarantine disease and according to South African regulations, the occurrence thereof should be reported to the National Department of Agriculture (NDA). After the identification of KB in South Africa, a KB Task Team was founded with the objective to compile protocols to limit the spread of the disease. These protocols include the testing of all registered seed units and all commercial grain for the presence of KB fruiting bodies called teliospores. It also involves the use of quarantine regulations and permits for the strict transportation of grain to specific intake points and mills.

Conditions conducive to the development of KB include optimum maximum temperatures of 16 – 23ºC, optimum minimum temperatures of 7 – 11ºC, mean daily relative humidity of more than 70% or minimum relative humidity of more than 48% and measurable rainfall over a few successive days. Typical symptoms (Fig.26) associated with KB include infected kernels that appear blackened and eroded and emit a foul ‘fishy’ odour. In infected spikes, the glumes may also appear flared and expose bunted kernels. Spikes of infected plants are generally reduced in length and in number of spikelets. However, it is very often difficult to identify the disease in the field, as the whole ear/plant does not necessarily become infested. A more reliable method involves microscopic examinations of seed lots for KB teliospores. These spores are easily distinguishable under a light microscope from the spores of the other smut diseases prevalent in South Africa (loose smut and stinking smut), hence an accurate diagnosis can be made and the necessary precautionary measures can be implemented.
With regard to control of KB, wheat producers are making use of seed certified free of KB spores. It is also advisable to treat seeds with Anchor Red (active ingredient: carboxin) as this fungicide has the ability to destroy any spores that may be present on the seed coat and may serve as a preventative measure before onset of the disease. In areas where KB has been identified, spraying twice with Triticonazole (Tilt or Bumper) is recommended. The first application is done at 25% ear emergence followed by a second application 10 days later. This spraying system is used by most wheat producers in the Douglas area with the purpose of limiting KB infection to levels below 2%.

Chemical practices alone are not sufficient to control disease-incidence. An integrated approach employing cultural control methods and chemical fungicides is recommended. Research has shown that high disease intensity is aggravated by high nitrogen applications, high planting densities and late planting dates. Splitting the application of nitrogen fertilisers showed lower disease incidence in comparison to a single application during planting. Crop rotation is also strongly advised. Break crops such as durum or barley serve as suitable alternatives to wheat in high-risk areas. It is also important to implement phytosanitary measures in quarantine areas to prevent movement of the pathogen out of the infested area. In this respect, all farming equipment and machinery should be washed with pressurized water before leaving a KB zone.

**Figure 26: Karnal Bunt**

### Disease more prevalent in the Western Cape

**Eyespot**

Eyespot, caused by *Pseudocercosporella herpotrichoides*, occurs on the stem bases/crowns of wheat plants. An infestation by this disease weakens the straw and yield losses occur mainly as a result of lodging prior to harvesting. Epidemic outbreaks of the disease mainly occur in the high rainfall regions of Koeberg and Swartland. In the Rûens area the disease occurs more sporadically. Aside from wheat, Bromus and Hordeum grasses also serve as alternate hosts for the fungus to complete its life-cycle. The application of crop rotation and the elimination of susceptible grasses may control the disease, however systemic fungicides are also available to help curb incidence and severity of an outbreak.
Weeds and weed control
A weed is a plant that persists to grow where it is not needed or a plant out of place. A maize plant that is found in a wheat field is a weed because it is not grown purposely and may compete with wheat crop.

Characteristics of weeds
(a) Weeds are highly prolific producing large quantity of seed per plant e.g. Chenopodium spp, Amaranthus spp.
(b) Weeds are persistent and resistant to their control and eradication.
(c) Weeds remain dormant and viable for 30 to 40 years.
(d) Weeds are hardy and can survive adverse climatic conditions.
(e) Weeds mimic certain crops and their separation from the crop is very difficult.
(f) Weeds can be propagated asexually or sexually.

Harmful effects of weeds
(a) Weeds compete with crops for light, nutrients and water.
(b) Weeds reduce the quality and quantity of farm produce.
(c) Weeds harbour diseases and pests.
(d) Weeds increase cost of labour and equipment.
(e) Presence of some weeds may cause depreciation of land value and thus reduce farm value.
(f) Some weeds are poisonous and cause health hazards to human beings and animals consuming them.
(g) Aquatic weeds impede water-flow in irrigation schemes, drainage, becoming menace to aquatic life e.g. fisheries.
(h) Weeds reduce recreational value of water bodies.
(i) Weeds reduce the carrying capacity of the rangelands and pastures.
(j) They grow very fast and out-compete the crop.

Beneficial effects of weeds
(a) Some weeds have medicinal value e.g. pot herbs, pharmaceutical industry.
(b) Weeds are used as source of germplasm in breeding programmes.
(c) Weeds are used as fodder for animals and vegetables for human beings.
(d) Some weeds are used for fencing purposes.
(e) Weeds, when incorporated into the soil, add organic matter content.
(f) Weeds are used as mulch to reduce evaporation losses of water from the soil.
(g) Some fix nitrogen in the soil.
(h) Provide vegetative cover that protects the soil surface against erosive action of rain and wind.
Classification of weeds
Weeds may be classified according to the following:
(a) Morphology-monocotyledon (sedge and grasses) - dicotyledon - legumes or nonlegumes.
(b) Life-cycle-annuals, biennials, perennials, ephemerals.
(c) Feeding habits-parasitic, autotrophic.
(d) Habit-terrestrial (obligate or facultative) or non-parasitic.
(e) Origin-indigenous or exotic weeds.
(f) Crop weed interaction-parasitic (obligate or facultative).
(g) Botanical nomenclature-parasitic (obligate or facultative) or non-parasitic.
(h) Herbaceous or woody.

Weed biology
(a) Weeds are asexually propagated. Asexually by stolons, rhizomes, bulbs, tubers and stem. Sexually by seed.
(b) Weed growth and development.

Dormancy
Weed seeds, like crop seeds, undergo dormancy when conditions are unfavourable. Once they become favourable they germinate. However, dormancy can be broken by chemical and physical means.

Dormancy is defined as the inhibited state of seeds growth due to internal and external factors. Internal factors include hormones, inhibitor chemicals. External factors include temperature, water, light and oxygen.

Types of dormancy
(a) Innate - mature viable seeds fails to germinate because of the inhibitors, enzymes.
(b) Induced - mature viable seeds fails to germinate because of after-ripening effects such as high level of carbon dioxide, allelochemicals.
(c) Enforced - mature viable seed is exposed to unfavourable conditions that will inhibit germination.

Phases of a germination process
(a) Imbibition of water – since the seed is dry, it absorbs water when planted in the moist soil until 40% of its weight consists of water.
(b) Activation of enzymes – when water is absorbed by seed, enzymes existing in the seed are being stimulated to act upon the compounds stored in the seed.
(c) Translocation of assimilates – energy being released during the break-down of stored compounds is being used by developing embryo.
(d) Embryonic growth.
The growth rate of the weeds is faster and over-shadows the crop. Weed seed population is the results of various factors:
(a) Accumulation of weed seeds in the soil.
(b) Transportation of weed seeds from other sources to the area.
(c) Crop seeds infested with weed seed.
(d) Losses due to birds, mice, ants, decay of seed in the soil.

Mode of dispersal of weed seed:
(a) Through impure seeds.
(b) Through organic manure not well decomposed.
(c) Through air and water.
(d) Through birds, animals and human beings.
(e) Through irrigation water and drainage.
(f) Through sludge and sewer.

Method of weed control
(a) Mechanical – use of hoes, harrows, cultivators, mowers, hand-pulling.
(b) Cultural – Crop rotation to avoid multiplication of weeds associated with a particular crop, kind of crop since some crops are highly competitive with weeds, use of fertiliser to stimulate crop growth thereby over-shadowing the weeds, early planting and high seed rate helps the crop to over-compete, burning, flooding, mulching.
(c) Biological – use of predators, parasites and pathogens.
(d) Chemical control – use of herbicides to control weeds.

Herbicides are classified according to the following:
- Methods of application (leaf applied or soil applied)
- Their chemical action on plants (contact or systemic)
- Time of application – pre-planting applied before planting
- Pre-emergence applied before emergency of weeds.
- Chemical composition – may be classified as carbonates, urs-trazine, amides, phenoxy acid
- Mode of action – act on plant metabolism, cell metabolism, cell division and elongation, inhibition of protein synthesis, translocation of apoplastic and sympoplastic pathways.
Absorption of herbicides by the plants

- Foliar absorption – the herbicides may act by contact or translocation, by contact the foliage is killed instantly.
- Translocation – the herbicides move in the plant, reaching young growing points and moving down the roots.
- Herbicides may gain entry through stomates or cuticle. Entry is rapid through stomates but during dry period, stomates close and herbicides do not enter the plant and dry off.
- Herbicides salts are popular (solution in water), while acid and esters are non-polar. Herbicide salts tend be absorbed rapidly through the leaf cuticle, comprised of non-polar materials. Polar herbicides absorption is improved by the additional of wetting agents.
- Root absorption – Herbicides are applied to the soil surface and be incorporated into upper soil layer by light cultivation, rain or irrigation, or may be injected below the surface of the soil. The herbicides are absorbed by the roots.

Movement of herbicides in the plant

- Translocation through phloem from the leaves to the other parts of the plant. The phloem may be killed if applied excessively. Herbicides applied on the soil is translocated through the xylem with the nutrients.
- In the roots thru sympoplastic and apoplastic pathways.

(a) Morphology - meristems of dicots plants are exposed to the action of the herbicide.
- corrugated leaves of cereals make it difficult for the herbicide to be in direct contact with the epidermis.
- Broad leaves have more surface area that makes the wide coverage of herbicide.
- Thickness of cuticle.
- Size and number of stomates.
- Leaf orientation – surface, area, hairiness.

(b) Physiology – Biological process impedes the movement of one herbicide in another species.
- A substrate in a plant neutralizes the toxic effect of the very herbicide in another species.
- Enzyme systems in the plant convert the compound into toxic substance.
- Inhibit synthesis of certain compounds.
Formulation
(a) Liquid-ultra-low, low and high volume
(b) Granule-good for long residual action
(c) Power-fine particles of a substance

Factors affecting the performance of herbicide
(a) Climatic conditions – high temperature increases the penetration of herbicides.
- Relative humidity – low HR reduce permeability of herbicide.
- High HR increases permeability.
- High temperature and low HR increase cuticle layer making penetration is slow.
- Light stimulates opening of the stomata and increases production of photosynthates which promotes movement of herbicide in the phloem.
- Rain increases hydration and turgor of tissues, thereby increasing wettability of the leaf.

(b) Soil conditions – Adsorption of herbicide by the soil – depends on
- The quantity and nature of its soil colloids –
- Heavy clay and soils with high organic matter content usually need higher application rates to be effective.
- Soil temperature and moisture conditions may influence uptake and volatization of herbicides.

Losses of encountered in herbicide applied
- Volatization – it is affected by high temperature.
- Photodecomposition – where light intensity (U.V) degrade herbicides attenuate its biological effects.
- Irrigation – water is more effective incorporating herbicides than mechanical equipment because a better penetration and more uniform incorporation.
Critical stages of crop growth for weed control
At seedling stage, crops suffer a great set-back due to high level of weed infestation. Once the crop canopy is above that of the weeds, weeding may no longer be needed.

Factors determining competitive ability of crops
(a) Variety – choose the variety of crop that is well adapted to the local conditions of the soil, water and climate. Choose the variety that grows vigorously.
(b) Tillage – the frequency, depth and time of cultivation.
(c) Soil water relations – quantity and distribution of rainfall has an effect on the growth of crops. High and frequent rainfall stimulates growth.
(d) pH status – encourage certain species of weeds to grow such oxalis. These species are used as indicators.
(e) High seed rate – results in high population density that can overcompete with weeds.
(f) Time of planting – where crop seeds are planted early and germinate before the weed seed do, this will give the crop an advantage.

Weeds are generally controlled using the following herbicides; Topic for wild oats, Glean and Brush off for broad leaf weeds. Where nut-sedge need to be controlled use Servian. These names given above are trade names that differ with manufacturers, but active ingredients may be the same. An adjuvant should be used with a herbicide so that droplets of the herbicides stick on the surface of the leaf. Instructions for mixing herbicide, water and adjuvant are indicated on the leaflet that is attached to the container. The stage at which the herbicide is applied is very important as young weeds are more easily killed than older ones.
The most problematic weeds in wheat

*Chenopodium spp*  
*Portulaca oleraceae*

*Buckwheat*  
*Avena fatua*

**Harvesting**
The wheat crop ripens 30 days after the blooming of florets. The kernels are completely filled when they reach the dough stage. At that time the leaves, stalks and spike begin to lose their green colour and become golden yellow. Wheat crop reaches physiological maturity between 35 to 45 percent moisture content, but it needs to dry down to safer moisture content for harvesting and storage. The seed moisture content can be used as an indicator of when the crop is ready for harvest. Electrical moisture meters can be used to measure seed moisture content. Average kernel moisture at which wheat can be stored is 10 – 12%. A combine harvester (Fig. 27) is used for harvesting on large farms. On small farms hand-cutting using sickles is popular. The most critical factors for storage to be considered are seed moisture content, mechanical damage and cleanliness of equipment.
Yield
It is of utmost importance to set a realistic yield for your cropping programme, taking into consideration all the available resources. Target yields are the foundation upon which decisions are made. Cultivar selection, fertiliser rates, herbicides applications and especially the financial planning and other management decisions can only be made with the aid of clear yield objectives. Various methods of setting a target can be considered:

(a) Experience – historical average yield plus 25%.
(b) Plant available water – sum of stored water just prior to planting, plus effective growing season rainfall.
(c) The risk associated with your selected yield goal should be carefully considered.
(d) Profit is the competition obtained from taking risk, but be realistic.
(e) Certain management practices and goals have a higher risk component.

What determines yield? Total grain yield is the product of:
(a) The number of plants per hectare.
(b) The number of heads per plant.
(c) Number of grains per head.
(d) Individual grain weight.
7. Storage and marketing

Storage

Produce should be harvested when physiological maturity is reached, dried to safe moisture content of 10 – 12%, stored under favourable conditions and protected from damage and pests until it is sold. The produce should be kept dry and cool in clean stores. When the produce is dry and cool, physiological processes, fungal activity and insect activity are low. The following are the conditions that need to be taken into consideration when storing wheat crop:

(a) Immature or damaged seed cannot survive long storage periods. Seed should be harvested when properly matured.
(b) Mechanical injury to seed during harvesting or handling makes it more susceptible to deterioration in storage.
(c) Seed should be properly dried before going into storage and protected from moisture and high relative humidity.
(d) High storage temperature has a damaging effect on seed. Store facilities should be designed so that low temperatures are maintained.
(e) Rodents, particularly, rats and mice, can be most destructive to the produce. Effective rodenticides are used. A complete programme of exclusion, sanitation and control should be in place.
(f) Insects should be controlled by a combination of insecticides and fumigants. Phostoxin is the safest, while methyl bromide may affect the produce.
(g) Controlled and airtight storage atmosphere is of utmost importance.
(h) Statutory regulations affecting the quarantine or control of storage insects.

Figure 28: Concrete silos used for storing wheat produce
Many small-scale farmers use grain storage structures that are inadequate to protect grain from rain or dampness and rodent or insect infestation. Appropriate storage facilities are available which can be purchased after obtaining an expert’s opinion. The concrete (Fig. 28) and corrugated iron silos are commonly used.

**Marketing**

**Grading**

The aim of grading is to determine the quality as well as the class and grade of the wheat. Wheat with the same class and grade (quality) can be mixed together. The class is determined by the cultivar and is an indication of the baking quality and properties of the wheat. The grade indicates the commercial value that is the quality and quantity of flour, is obtained from the wheat. The three primary grading factors used for grading wheat are hectolitre mass, falling number and protein content. If nothing else that can downgrade your wheat is present – like frost damage, field and storage fungi, screenings or damaged kernels (immature, heat- or insect-damaged or sprouted kernels) – these three factors are sufficient to grade the wheat (Refer to production guideline).

With the advent of free market liberalization and abolishment of regulated market, many channels are open through which wheat can be sold. This means that wheat can be sold to whoever pays a satisfactory price to the producer as long as the buyer is willing to buy at that price. The conditions for sales could either be verbal or documented.

**Contracts or direct marketing**

Wheat can be sold through contracts with grain companies or millers. Wheat can also be sold through SAFEX – stock exchange for commodities. These contracts can be signed before the planting season whereby the price and quantity are stipulated on the contract. If the producer fails to supply the quantity and quality of wheat stated in the contract, she or he is surcharged. Another channel is direct marketing, where produce is usually sold directly after harvesting. In most cases, this last option realizes the highest price.

**Marketing after storage**

Wheat can also be stored and sold at a later stage, hopefully at a higher price. In this case, a producer needs the necessary infrastructure to store the grain safely – see above paragraph on storage.

**Price**

The wheat price in South Africa is closely related to international prices. Supply and demand is playing a major role in determining the wheat price.
Recommendation
It is recommended that a farmer sells part of his wheat crop through contracts, a part directly to grain companies or millers and a part stored and sold at a later stage. As the saying goes: do not put all your eggs in one basket. This all depends on a producer’s circumstances with regard to infrastructure and finance. The whole process of post – harvest handling in wheat production involves the capital.

For further information, please contact:
Agricultural Research Council
Small Grain Institute
Private Bag X29
Bethlehem
9700
Telephone: 058 307 3400

8. Other useful information

A. Contacts for specialists

<table>
<thead>
<tr>
<th>NAME</th>
<th>SPECIALITY</th>
<th>PLACE</th>
<th>TEL/CELLPHONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>W.H. Kilian</td>
<td>Plant Nutrition</td>
<td>Bethlehem</td>
<td>(058) 307-3498</td>
</tr>
<tr>
<td>J.P. Tolmay</td>
<td>Soil Tillage</td>
<td>Bethlehem</td>
<td>(058) 307-3422</td>
</tr>
<tr>
<td>T. Terefe</td>
<td>Disease Control</td>
<td>Bethlehem</td>
<td>(058) 307-3440</td>
</tr>
<tr>
<td>A. Barnard</td>
<td>Crop Physiology</td>
<td>Bethlehem</td>
<td>(058) 307-3411</td>
</tr>
<tr>
<td>C. Miles</td>
<td>Quality laboratory</td>
<td>Bethlehem</td>
<td>(058) 307-3414</td>
</tr>
<tr>
<td>L. Visser</td>
<td>Soil laboratory</td>
<td>Bethlehem</td>
<td>(058) 307-3401</td>
</tr>
<tr>
<td>W. Lemmer</td>
<td>Marketing Grain SA</td>
<td>Bothaville</td>
<td>(056) 515-0922</td>
</tr>
<tr>
<td>A. Malan</td>
<td>Plant Breeding</td>
<td>Bethlehem</td>
<td>(058) 307-3430</td>
</tr>
<tr>
<td>S. Msibi</td>
<td>Agricultural Information</td>
<td>Pretoria</td>
<td>(012) 319-6380</td>
</tr>
<tr>
<td>G. Prinsloo</td>
<td>Pest Control</td>
<td>Bethlehem</td>
<td>(058) 307-3435</td>
</tr>
<tr>
<td>General Inquiries</td>
<td>Farm Machinery and Implements</td>
<td>Silverton - ARC</td>
<td>(012) 842-4017</td>
</tr>
</tbody>
</table>

B. Calibrations
(a) Calibration of wheat planter
Step 1 – Hitch a planter to the three-point linkage of a tractor squarely. Look for a flat clean ground without obstructions. Lift the planter from the ground using hydraulic system to the sufficient height that can allow you to move the driving wheel freely and put the containers below the furrow opener.

Step 2 – Measure the circumference of the driving wheel. Decide the distance that you want to use for calibration, more often 50 meters is used. Then divide 50 metres by the circumference of the wheel to get the number of revolutions that wheel will travel to cover 50 metres.

For further information, please contact:
Agricultural Research Council
Small Grain Institute
Private Bag X29
Bethlehem
9700
Telephone: 058 307 3400
Step 3 – Measure the width of the planter that is going to be used. Multiply the width by 50 metres to get an area where seed would be planted. Then calculate the amount of seed that has to be applied on this area as per recommendations from production guidelines.

Step 4 – Put wheat seed into the seed hopper and try to spread it evenly along the length of the hopper. Fasten the plastic bags on the furrow opener where seed is dropped during planting. Open the aperture of the seed hopper where the seed is regulated using the graduations provided. Select mark that you think when chosen, seed that would go through the aperture would deliver the amount of seed that is close to what you require. Turn the driving wheel, the number of times that would cover 50 meters. Maintain constant speed when turning the wheel.

Step 5 – Remove plastic bags that are now containing seed, weigh seed in each plastic bag separately. Ensure that the amount of seed in each plastic bag is the same, otherwise adjust the aperture of seed to deliver similar amount. If the total amount of seed from all plastic bags is lower than the recommended rate, increase the aperture on the seed hopper to allow more seed to go through. But if the amount of seed going through is high, it reduces aperture size. This has to be repeated several times until the correct rate is obtained by adjusting aperture size.

For example:
Distance is 50 metres
Circumference of driving wheel is 1.5 metres
Width of planter is 3 metres
Six row planter
Row spacing is 50 cm
Seed rate per hectare is 25 kg (25000 g)

No of revolutions = 50 metres
1.5 metres

= 33.3 revolutions (turns)

Area to be tested on
50 m x 3 m = 150 m²

Amount that has to be delivered on an area of 150m²

= 150 m² x 25000 g
10 000 m²

= 375 g of seed should be from six rows of planter

So from each row, an amount of 62.5 g should be delivered to apply 25 kg or 25 000 g.
(b) Calibration of a boom sprayer

Step 1 = The boom sprayer has a pamphlet which shows the speed at which the tractor has to travel and the pressure at which the liquid in the sprayer tank has to be discharged.

Step 2 = Measure a distance of 50 metres on the level ground. Time the sprayer over the measured distance.

Step 3 = Determine the delivering capacity of the boom for the same time by adding the volumes for all the nozzles together. Water from a single nozzle sprayer is collected directly in to measuring cylinder.

Step 4 = Determine the spray width of a tractor sprayer by measuring the distance of the wet soil underneath boom. Multiply the spray width with the measured distance to get an area in m².

Step 5 = Divide area into 100 000 m² to get a factor. Multiply the volume collected in the measuring cylinder with a factor to determine the delivering capacity of the sprayer on a hectare.

Step 6 = The following information is necessary to determine the amount of pesticides that must be mixed in the tank filled with water:

- Amount of water that should be used to mix the pesticides.
- The recommended rate of pesticide as per label
- The delivering capacity of the sprayer on hectare.

Amount of pesticide to be applied
\[ = \frac{\text{Amount of water} \times \text{Amount of pesticides in litre / ha}}{\text{Delivering capacity of the sprayer / 1 ha}} \]

D. Common names (including names used by different communities in South Africa):

<table>
<thead>
<tr>
<th>Language</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>Wheat</td>
</tr>
<tr>
<td>Sotho</td>
<td>Koro</td>
</tr>
<tr>
<td>Zulu</td>
<td>Kolo</td>
</tr>
<tr>
<td>Xhosa</td>
<td>Nqolowa</td>
</tr>
<tr>
<td>Afrikaans</td>
<td>Koring</td>
</tr>
</tbody>
</table>
### E. Production levels and areas producing wheat in South Africa

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Cape</td>
<td>691 000</td>
<td>804 100</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>324 800</td>
<td>270 000</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>Free State</td>
<td>908 000</td>
<td>1 035 000</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>Eastern Cape</td>
<td>14 500</td>
<td>9 280</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>KwaZulu-Natal</td>
<td>43 700</td>
<td>50 600</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>102 000</td>
<td>102 500</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>Limpopo</td>
<td>75 000</td>
<td>46 500</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>Gauteng</td>
<td>18 000</td>
<td>13 200</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td>North West</td>
<td>171 550</td>
<td>161 700</td>
<td>Ns</td>
<td>Ns</td>
<td>Ns</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2 348 550</td>
<td>2 492 880</td>
<td>1 540 000</td>
<td>1 680 000</td>
<td>1 905 000</td>
</tr>
</tbody>
</table>

**Note:** *Ns: Not specified

**Source:** CEC

### F. International trends in wheat yields (t/ha)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>1.41</td>
<td>1.86</td>
<td>2.37</td>
<td>2.84</td>
<td>3.02</td>
</tr>
<tr>
<td>Africa</td>
<td>0.93</td>
<td>1.10</td>
<td>1.45</td>
<td>1.96</td>
<td>2.18</td>
</tr>
<tr>
<td>Asia</td>
<td>N/a</td>
<td>N/a</td>
<td>N/a</td>
<td>2.15</td>
<td>2.87</td>
</tr>
<tr>
<td>Europe</td>
<td>N/a</td>
<td>N/a</td>
<td>N/a</td>
<td>2.86</td>
<td>3.81</td>
</tr>
<tr>
<td>North &amp; Central America</td>
<td>1.86</td>
<td>2.26</td>
<td>2.49</td>
<td>2.79</td>
<td>2.88</td>
</tr>
<tr>
<td>Oceania</td>
<td>1.36</td>
<td>1.44</td>
<td>1.53</td>
<td>1.97</td>
<td>1.95</td>
</tr>
<tr>
<td>South America</td>
<td>1.40</td>
<td>1.42</td>
<td>1.86</td>
<td>2.31</td>
<td>2.42</td>
</tr>
<tr>
<td>South Africa</td>
<td>0.71</td>
<td>1.03</td>
<td>1.36</td>
<td>2.01</td>
<td>2.61</td>
</tr>
<tr>
<td>South Africa as a % of World</td>
<td>50.3</td>
<td>55.4</td>
<td>57.4</td>
<td>70.8</td>
<td>86.4</td>
</tr>
</tbody>
</table>