HANDBOOK OF GOOD AGRICULTURAL PRACTICES
for ***Durum Wheat*** production

tresmontes lucchetti

Grupo nutresa

INIA

commitment & leadership

The quality of our products is directly linked to their ingredients quality, which is why we have assumed leadership in development of Durum Wheat production in our country since a while already, through a private-public agreement between Lucchetti and the Institute of Agricultural Research (INIA), which supports and encourages investigations of Durum Wheat since 1988. Creating and selecting genetic material adapted to different production areas has been our main objective, gathering suitable features in order to produce high quality pasta.

This agreement has allowed us to provide constant support to farmers linked to Luchetti through workshops and field trips conducted with the INIA.

On the other hand, in order to boost the Durum Wheat production in a sustainable way, our historic agreement with the INIA was renamed "SUSTAINABLE DEVELOPMENT PROGRAM OF DURUM WHEAT FOR CHILE", starting in 2016, giving a step forward in generating value offers, not only for the company and our suppliers, but also for the final consumers.

This "Handbook of Good Agricultural Practices for Durum Wheat Production" is a concrete example of our commitment to sustainable development of crop, which we hope will be a contribution in terms of knowledge, which allows our farmers to give a boost in competitiveness and sustainability of durum wheat production in Chile.

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introduction

GOOD AGRICULTURAL PRACTICES (GAP) / DURUM WHEAT

THE WORLD FOOD MARKET IS TODAY BETTING FOR PRODUCING HEALTHIER, SAFER AND MORE NUTRITIOUS FOODS, OBTAINED THROUGH A SUSTAINABLE PRODUCTION CONCEPT, REASON WHY THE CONCEPT OF GOOD AGRICULTURAL PRACTICES (GAP) HAVE BEEN INCORPORATED INTO THE AGRICULTURAL SCOPE. THE GAP CONSIST ON A GROUP OF MEASURES THAT INTEGRATE A WIDE RANGE OF ASPECTS SUCH AS LABOUR SECURITY, FOOD SAFETY AND ENVIRONMENTAL PROTECTION.

Application of GAP is a gradual process that requires work methodologies being adopted by the agricultural producer, which tend to adjust their traditional tasks to the new market demands both, internally and globally.

Given this challenge, INIA Chile together with TRESMONTES LUCCHETTI S.A., have developed this GAP handbook for durum wheat production, with the purpose that farmers who are related to this productive area incorporate practical recommendations applicable to its productive scale, for its fast and safe implementation. In this way, we will contribute to generate a sustainable and competitive agricultural system, in a world where both food industry and consumers are increasingly demanding.

In this hanbook are addressed, establishing control mechanism of them, which will allow the farmer to handle his crop through an efficient use of resources.

For better understanding, this manual has been divided into the following themes:

1- CROP PHENOLOGY
2- STUBBLE HANDLING
3- AGRONOMIC MANAGEMENT
- **a)** Soil preparation
- **b)** Election of variety
- **c)** Sowing
- **d)** Fertilization
- **e)** Phytosanitary management
- **f)** Irrigation
- **g)** Harvest

4- DURUM WHEAT QUALITY

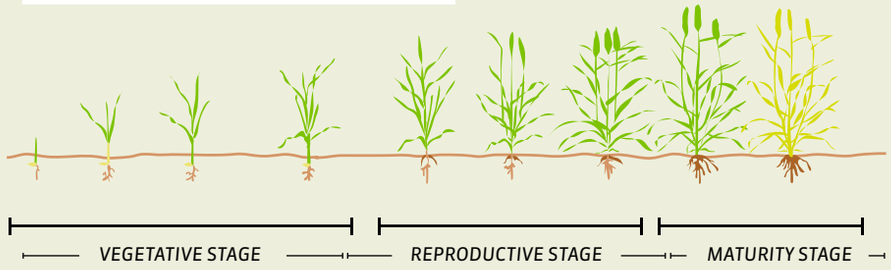
1.

CROP PHENOLOGY

CROP PHENOLOGY IS DEFINED AS THE SEQUENCE OF DEVELOPMENT STAGES CONTROLLED BY GENETIC, AGRONOMIC AND ENVIRONMENTAL FACTORS. THESE FACTORS DETERMINE MORPHOLOGICAL AND FUNCTIONAL CHANGES INTO THE WHEAT PLANT AND THAT BRING IT TO GROWTH AND CROP DEVELOPMENT. IT EXPRESSES IN THE ACCUMULATION OF BIOMASS AND IN THE DEVELOPMENT OF YIELD COMPONENTS AND FINAL YIELD GRAIN.

Under this concept, we can identify three major stages or periods in wheat development: vegetative, reproductive and maturation (Figure 1)

Figure 1. Wheat development stages or periods



Each period comprises several phases which are chronologically described in **Figure 1**.

The development of each one of these components occurs sequentially at different times in wheat plant cycle. This is the reason why it is important to optimize the expression of each of them from stage 1, since they are all related to each other and any adverse effect on any of them will have negative effects on their final grain yield.

However, and under certain conditions, wheat plant is able compensate the negative effect on a component by increasing the expression in some of its other components. The durum wheat grain yield is determined by the interaction of these five components:

1. - number of plants / m2,
2. - number of tillers / m2,
3. - number of spikes /m2,
4. - number of grains / spikes and
5. - weight of grains

Figure 1. Phenological wheat stages description

1.

Germination
Radicle and coleoptile emerge from the seed

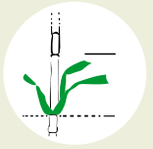
2.

Seedling
From first to third leaf

3.

Tillering
It starts once the main stem has developed three leaves

4.



Stem elongation
When the fourth leaf is formed, the first node appears and with the fifth leaf the second one. At the beginning of the stem elongation, internodes lengthen, and nodes move to the top of the plant. This stage ends with the appearance of the flag leaf.
In this period, the spike has already formed all the spikelets (reproductive stage).

5.

Booting
The already formed spike develops itself inside the flag leaf sheath.

6.

Heading
Corresponds to the stage where a spike emerges from a pod of the flag leaf. It lasts ten days approximately.

7.

Flowering or anthesis
Pollination and fertilization occur. An off-white watery grain forms itself, containing about 64% humidity (± 15 days). By squeezing the grain with fingers, it obtains a watery liquid.

8.

Milk grain
The grain increases in size and contains between 45 to 50% humidity. By squeezing the grain with fingers, it obtains a whitish, milky liquid.

9.

Dough grain
The grain formation is completed, and it contains between 40 and 45% humidity (± 10 days). By squeezing the grain with fingers, a soft dough is formed.

10.

Hard grain
The nutrients transference from the leaves, stem and spike to the grain stops. The state of physiological maturity has been reached. The moisture content of grain is approximately 35 to 40% and its coloration is yellowish.

11.

Grain maturity
The plant dries from the base upwards and could be harvested when the grains present humidity of 14 to 12%, which takes ± 8 days.
The grain is very hard and ready to harvest.

2.

MANAGEMENT OF CROP RESIDUES

BURNING LAND IS ONE OF THE MOST USED PRACTICES TO FACILITATE SOIL MANAGEMENT PRIOR SOWING, IN ORDER TO ELIMINATE VEGETAL STUBBLE OR RESIDUES. HOWEVER, IT HAS BEEN DEMONSTRATED THAT THIS PRACTICE IS VERY HARMFUL AND INCREASES EROSION ISSUES AS WELL, SINCE SOIL BECOMES FULLY EXPOSED AND VULNERABLE TO RAIN AND WIND EFFECTS AVAILABLE ORGANIC MATTER IS ELIMINATED; IMPORTANT NUTRIENTS SUCH AS N, P, K, S ARE LOST, IN ADDITION TO POLLUTION AND ECOSYSTEM ALTERATIONS.

Given the above, it is proposed to incorporate stubble (1 to 2 ton / ha) by inverting the soil and burying them to 25-30 cm depth of soil; and / or mix them in the first 15-20 cm allowing its faster decomposition. It is recommended the use of a combine with a stubble picker and / or stubble spreader when harvesting.

Once the harvest is over, it is also recommended to chop residues left on the ground in order to incorporate them into the soil.

Adopting this task in the field, will represent a series of advantages for farmers, such as increase of organic matter content in soil and fertilizer saving in the medium term, since when incorporating stubble, the levels of N, PK, S, Ca, Mg and other micronutrients increase.

Although the advantages of this task are clear, not proper management of stubble may present a significant problem from a nutritional point of view called “Hunger of Nitrogen”. This is a nitrogen immobilization in the soil produced by microorganisms. This occurs when soil residues have more carbon than nitrogen, so when the microorganisms decompose them, the stubble nitrogen is not enough to supply microorganisms’ requirements. For this reason, N availability for plants is reduced.

This problem can be solved by performing tasks that accelerate and facilitate the stubble decomposition in soil.

Another alternative to the incorporation is to baler the stubble to remove them from the field afterwards. It is also possible to remove a percentage and to incorporate another part, considering the positive effect of incorporation.

3.

CROP MANAGEMENT

A. SOIL PREPARATION

▪ **Soil analysis:** Knowing physical and chemical characteristics of the soil that we chose to establish the crop is very important because in this way we can estimate the available nutrients and design a fertilization strategy and correction of limiting elements for our production.

The information provided by the analysis is soil pH, which shows its acidity degree in order to fix it by applying lime if necessary; nitrogen (N) must be the most contributing element followed by phosphorus (P) and potassium (K). Microelements, especially Zn levels, should also be considered.

CHECK POINT Nº1

pH levels

Performing soil analysis before sowing durum wheat is very important, since it has special requirements for some microelements and acidity levels.

▪ **Weed control:** Our weed control strategy should consider facing this issue in two ways: Pre and post sowing.

1. *Before sowing*
Utilize strategies aimed to reduce the amount of weed seed present in the field where we will plant the crop.
Some of the factors that allow us to reduce the effect of weeds on wheat development are:

▪ *Crop rotation* With this simple task, which consists on alternating different crop species in the same field, it cuts the weeds cycle present in the soil, facilitating the development of the next crop, achieving effective control of many of them. Additionally, the field is directly benefited in aspects such as organic matter content, erosion reduction, soil structure improvement and pest's cycle cut

▪ *Weed traps* They are low cost simple structures installed in water irrigation entrances that reduce enough the amount of weeds transported in the water.

▪ *Soil preparation* Before performing this task, it is important to consider the soil moisture in order to prevent compaction problems.

In the same way, it is important to incorporate residues from the previous crop as early as possible in the season, since this will allow an adequate decomposition of it, leaving available nutrients for proper development of the plants.

Avoiding the excessive use of machinery to prevent soil compaction and cleaning machinery properly of any residue of previous crop that produce seeds or allow its propagation is also very recommendable.

Regarding herbicides, there is a wide range available to farmers to access to, however identifying weeds in soil is very important for a correct application of these products in order to obtain good results.

2. *After sowing*
It is very important, at this point, checking constantly the crop in the field in order to identify weeds present in it and their development status. And in this way it is possible to plan a control strategy. Additionally, we must find out if there were resistant plants in that field and the herbicides use history. In this way, we can decide a use of herbicides according to their mode of action and thus to perform a more efficient control.

B. CHOOSING SEED VARIETY

About 90% of durum wheat area in Chile are sown with varieties developed by the Wheat Genetic Improvement Program of Agricultural Research Institute (INIA), which offers in this moment, four varieties such as Llareta- INIA, Corcolén-INIA, Lleuque-INIA and Queule-INIA, whose most relevant agronomic characteristics are shown in **Table 3**.

Table 3. Agronomic features of INIA durum wheat varieties.

TRAIT	VARIETY			
	Llareta INIA	Corcolén INIA	Lleuque INIA	Queule INIA
Height (cm)	85-95	85-95	80-90	85-95
Thousand kernel weight (gr)	50-58	50-58	65-70	55-60
Hectoliter weight	84-87	84-87	81-86	83-86
Protein content (%)	10.3-10.7	10.5-11.7	10.5-12.3	10.5-11.5
Vitreousness	95-98	95-98	90-95	95-98

The INIA varieties are characterized by resistance to both, stripe rust and leaf rust even with the crop relocation to Bío Bío Region.

Table 4 shows behavior of each variety to different diseases present in the country.

Table 4. Behavior of INIA Durum Wheat varieties to diseases

DISEASE	VARIETY			
	Llareta INIA	Corcolén INIA	Lleuque INIA	Queule INIA
Stripe rust	R	R	R	R
Leaf rust	R	R	R	R
Powdery mildew	MS	MS	MR	MS
Septoria blotch	**	**	**	**

R: resistant, **MR:** moderately resistant, **MS:** moderately susceptible,
****:** Sowings from June onwards escape the disease.

▪ *Use of certified seed:* Seed that ensures high vigor, viability and purity, that is, it has a high germination power and is free of other wheat seeds and / or weeds. Given these features, the use of this seed is highly beneficial for producers since it guarantees an adequate establishment and initial development of the crop.

▪ *Planting date:* The sowing zone of durum wheat in Chile extends from the Metropolitan Region to the Bíobío Region. INIA delivers specific recommendations for each variety depending on the area in which it is established.

Table 4. Planting date of INIA Durum Wheat varieties in different geographical areas.

ZONE	VARIETY			
	Llareta INIA	Corcolén INIA	Lleuque INIA	Queule INIA
Northern Centre (From Metropolitan region up to Curicó)	June July	June July	June July	June July
Southern Centre (Curicó up to Bío Bío)	August 15 Sept	August 15 Sept	August 15 Sept	August 15 Sept

R: Resistance, **MR:** Moderately resistance, **MS:** Moderately susceptible,
****:** Sowings from June onwards escape the disease.

CHECK POINT Nº2

planting date — *According to recommendation for INIA varieties in each zone.*

▪ *Seed rate:* the seed rate is directly related to the amount of viable grains that should be sown. In case of durum wheats, the dose is higher than bread wheats due to the grain is larger and heavier.
To perform calculation, three factors must be considered: plants per m2; seed weight (mg) and germination %.

Based on the formula used at Fundacion Chile (2011) crop check manual for durum wheat, we will do the following exercise for Llareta-INIA, this variety weighs on average 55 mg, has a germination percentage of 90% and we need to establish a population of 393 plants per m2.
So:

$$\text{Seed rate (kg/ha)} = \frac{\text{plants per m2} * \text{Seed weight (mg)}}{\text{seed germination (\%)}}$$

$$\text{Seed rate (kg/ha)} = \frac{393 \text{ plants per m2} * 55 \text{ (mg)}}{90 \text{ (\%)}}$$

Seed rate (kg/ha) = 240 kg/ha

A high plant population is considered due to there may be additional losses to the establishment produced by biotic or abiotic factors, such as animals, insects, drought, frost, among others. This additional percentage of losses is estimated at 10%.

C. SOWING

Once machinery to be used for planting is defined, it is essential to clean the equipment properly, leaving no traces of dirt or plant residues that could be carriers of any disease or plague.

Machinery to be used at this stage should be correctly regulated, taking care that it corresponds to the seed size. It is also important to consider the proper functioning of machine's fertilizer outlet.

▪ *Sowing depth:* This is an important issue to be considered in planting planning. In general, in heavy soils the seed should be at a lower depth than in light soils. But it must be careful, because if soil surface is very dry it is advisable to sow deeper, but no more than 5 cm.

CHECK POINT Nº3

clean and calibrated machine — *Sowing depth, no more than 5 cm.*

Once durum wheat being sown, we must observe in field to verify its good development and avoid any inconvenience that may affect production and final yield. Therefore, we will next review check points to follow.

▪ ***Plant population:*** we must bear in mind that the optimum quantity of population is 350 plants per m2 (Fundación Chile, 2011).
To perform counting we should wait until plants have two leaves and then calculate by applying the following formula:

$$\frac{\text{Nº of tillers per lineal meter}}{\text{Distance between rows (cm)}} * 100 = \text{Plants per m2}$$

In tiller, Fundación Chile (2011), indicates as optimum between 500 to 600 tillers per m2, which may be calculated applying the following formula:

$$\frac{\text{Nº of tillers per lineal meter}}{\text{Distance between rows (cm)}} * 100 = \text{Tillers per m2}$$

The importance of having a well-developed wheat in tiller is because if the soil surface is well covered, more radiation is intercepted and, therefore, the crop yield increases.

The crop is also more competitive against weeds. However, it must be borne in mind that an excessively high number of tillers per square meter brings an increase in fungal diseases and lodging.

CHECK POINT Nº4

plant population in two stages

Wheat with 2 leaves. Population of plants 200 to 350 plants m2. Tiller 500-650 tillers m2.

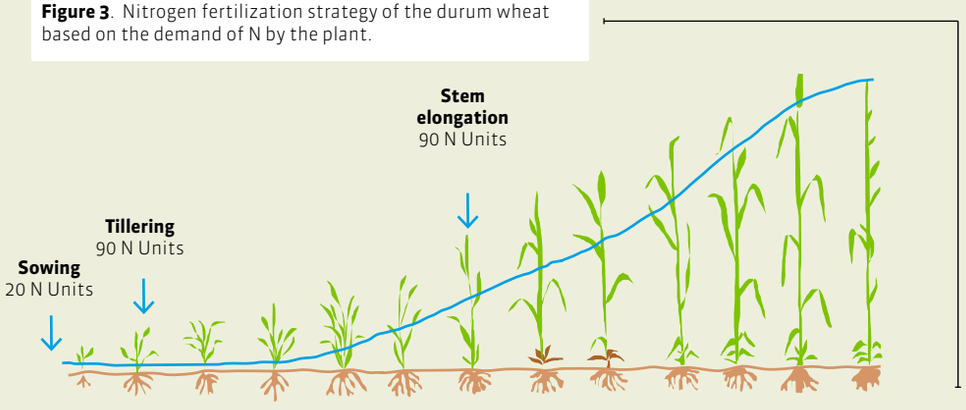
D. DURUM WHEAT FERTILIZATION

In the irrigated valley of the southern Centre zone of Chile, some research carried out by the INIA, showed a positive response of durum wheat grain yield to the application of increasing doses of N in three partialities (20 units at sowing, 90 units at tillering, and 90 units at the stem elongation). With maximum grain yield of 200 kg. ha-1 nitrogen (N).

Regarding partialization strategies of N, it has been observed that combinations that consider applications in sowing, tillering and flag leaf, increase grain yield and gluten content.

In **figure 3** we can see that in the first stages of the development of the plant, the required N level is low. From stem stage absorption capacity of N increases.

Figure 3. Nitrogen fertilization strategy of the durum wheat based on the demand of N by the plant.



Studies related to agronomic management of durum wheat, have allowed to determine the effects on the application of different nutrients and its application strategy on crop. Specific functions of each nutrient in this crop are presented in **Table 6**.

Tables 7, 8 y 9 provide orientation regarding fertilization, levels present in three types of soils and requirements for a high yield in durum wheat.

However, performing a soil analysis on the site to be use for seasonal planting is fundamental.

Table 6. Functions of the most important nutrients for durum wheat, deficit symptoms and moment of application.

Element	Deficit symptoms	Application moment
N NITROGEN	Poor tillering and small foliar area; number of spikes per unit area and grains number per spike reduces. Its observes generalized leaves chlorosis, appearing firstly in basal leaves while upper ones remain green.	20 units at sowing, 90 units at tillering and 90 units at stem elongation.
P PHOSPHORUS	Decrease in the stem / root ratio. Symptoms begin in oldest leaves characterized by a blue-green to reddish coloration that usually start from the margins.	Correction of P deficiency in soil is achieved through sowing fertilization, where the dose to be used is based upon type of soil and deficiency magnitude.
K POTASIUM	Chlorosis along the edge of oldest leaves, followed by a burn. Plants present lower stature, shortened internodes, slow and squat growth, weak stems susceptible to lodging, higher incidence of pests and diseases, lower grain yield and low-quality grains.	To sowing according to soil analysis.
Ca CALCIUM	Ca deficiency occurs first at growth points in youngest leaves.	Deficient Ca concentration in soil translates into low pH, which is corrected with calcareous amendments.
Zn ZINC	Symptoms of deficiency and application response of this nutrient have been reported in southern Centre region of Chile and can be identified by brown dry stripes in mature leaves of wheat plant, which are normally associated to previously lime treated soils and / or lack of humidity during the crop cycle.	To sowing according to soil analysis.
OTHER MICRO-ELEMENTS	Chlorosis, thin and sparse plants. Concentrations of other micronutrients in wheat grain correspond to 26.5 to 32.1 mg kg-1 for iron (Fe); 13.4 to 16.7 mg kg-1 for manganese (Mn); and 2.01 to 4.10 mg kg-1 for copper (Cu).	To sowing according to soil analysis.

Table 7. Durum wheat fertilization guide in Andisols, potential grain yield 80 to 100 qqm ha-1.

Nutrient to apply	Used soil parameter or handling as a dose indicator	Used reference value used in recommendation	Referential nutrient dose (kg ha*1)
N *	Organic matter (%)	< 6 6 - 10 > 10	280 - 300 260 - 275 240 - 250
P_2O_5 **	P Olsen (mg kg^{-1})	< 8 8 - 16 > 16	160 - 180 140 - 160 120 - 140
K_2O **	K interchangeable (cmol + kg^{-1})	< 0,25 0,25 - 0,4 > 0,4	130 - 160 100 - 130 80 - 100
$CaCO_3$ ***	pH	< 5,5 5,5 - 6,0 > 6,0	3.000 - 4.000 2.000 - 2.500 0 - 1.500
MgO ****	Mg interchangeable (cmol + kg^{-1})	< 0,8 0,8 - 1,2 > 1,2	30 - 40 20 - 25 10 - 15
S	S available (mg kg^{-1})	< 8 8 - 12 > 12	20 - 30 15 - 20 10 - 15
B	B available (mg kg^{-1})	< 0,5 0,5 - 1 > 1	1 - 1,5 0,5 - 1 0 - 0,5
Zn	Zn available (mg kg^{-1})	< 0,5 0,5 - 1 > 1	1,5 - 2 1 - 1,5 0,5 - 1

***** N must be splited 20-25% at sowing, 40-50% starting tiller and 25-40% at the beginning of stem stage.
****** If there is residues incorporation, use 70% of suggested dose as P2O5 and 50% of suggested dose as K2O.
******* The dose of CaCO3 corresponds to pure calcium carbonate. It must be converted to commercial lime according to relative neutralization power (PRNT) of used product.
******** In case of using MagnecalTM (CaCO3*MgCO3), MgO's contribution at any dose exceeds reference dose of MgO indicated in this Table, by saving MgO on applying to seed mix.

Table 8. Fertilization guide durum wheat cultivation in loamy clay soils, potential grain yield 70 to 90 qqm ha-1.

Nutrient to apply	Used soil parameter or handling as a dose indicator	Used reference value used in recommendation	Referential nutrient dose (kg ha*1)
N *	Organic Matter (%)	< 3 3 - 5 > 5	270 - 280 250 - 265 230 - 240
P_2O_5 **	P Olsen (mg kg^{-1})	< 8 8 - 16 > 16	140 - 150 120 - 130 100 - 110
K_2O **	K interchangeable (cmol + kg^{-1})	< 0,3 0,3 - 0,5 > 0,5	140 - 160 100 - 130 70 - 90
$CaCO_3$ ***	pH	< 5,5 5,5 - 6,0 > 6,0	3.000 - 4.000 2.000 - 2.500 0 - 1.000
MgO ****	Mg interchangeable (cmol + kg^{-1})	< 0,8 0,8 - 1,2 > 1,2	30 - 40 20 - 25 10 - 15
S	S available (mg kg^{-1})	< 8 8 - 12 > 12	30 - 40 20 - 25 15 - 20
B	B available (mg kg^{-1})	< 0,5 0,5 - 1 > 1	1,2 - 1,8 0,6 - 1,2 0 - 0,6
Zn	Zn available (mg kg^{-1})	< 0,5 0,5 - 1 > 1	1,6 - 2,2 1,2 - 1,6 0,6 - 1,2

***** N must be splited 20-25% at sowing, 40-50% starting tiller and 25-40% at the beginning of stem stage.
****** If there is residues incorporation, use 70% of suggested dose as P2O5 and 50% of suggested dose as K2O.
******* The dose of CaCO3 corresponds to pure calcium carbonate. It must be converted to commercial lime according to relative neutralization power (PRNT) of used product.
******** In case of using MagnecalTM (CaCO3*MgCO3), MgO's contribution at any dose exceeds reference dose of MgO indicated in this Table, by saving MgO on applying to seed mix.

Table 9. Fertilization guide for durum wheat cultivation in alluvial soils, potential yield 70 to 90 qqm ha-1.

Nutrient to apply	Used soil parameter or handling as a dose indicator	Used reference value used in recommendation	Referential nutrient dose (kg ha*1)
N *	Organic matter (%)	< 3 3 - 5 > 5	260 - 270 240 - 255 220 - 235
P_2O_5 **	P Olsen (mg kg^{-1})	< 8 8 - 16 > 16	120 - 140 100 - 120 80 - 100
K_2O **	K interchangeable (cmol + kg^{-1})	< 0,25 0,25 - 0,4 > 0,4	120 - 140 90 - 110 70 - 80
$CaCO_3$ ***	pH	< 5,5 5,5 - 6,0 > 6,0	3.000 - 4.000 2.000 - 2.500 0 - 1.000
MgO ****	Mg interchangeable (cmol + kg^{-1})	< 0,8 0,8 - 1,2 > 1,2	25 - 30 20 - 25 10 - 15
S	S available (mg kg^{-1})	< 8 8 - 12 > 12	20 - 30 15 - 20 10 - 15
B	B available (mg kg^{-1})	< 0,5 0,5 - 1 > 1	1 - 1,5 0,5 - 1 0 - 0,5
Zn	Zn available (mg kg^{-1})	< 0,5 0,5 - 1 > 1	1,5 - 2,0 1,0 - 1,5 0,5 - 1,0

***** N must be splited 20-25% at sowing, 40-50% starting tiller and 25-40% at the beginning of stem stage.
****** If there is residues incorporation, use 70% of suggested dose as P2O5 and 50% of suggested dose as K2O.
******* The dose of CaCO3 corresponds to pure calcium carbonate. It must be converted to commercial lime according to relative neutralization power (PRNT) of used product.
******** In case of using MagnecalTM (CaCO3*MgCO3), MgO's contribution at any dose exceeds reference dose of MgO indicated in this Table, by saving MgO on applying to seed mix.

D. PHYTOSANITARY MANAGEMENT

The Chilean durum wheats present very good phytosanitary features. Only a few diseases may affect it, since durum varieties such us Llareta-INIA, Lleuque-INIA, Corcolén-INIA and Queule-INIA present resistance genes against three types of rusts present in the country (Stripe Rust = Puccinia striiformis, rust = P. triticina and stem rust = P. graminis), in addition to moderate resistance to leaf rust (leaf blotch tritici-repetis).

Disease management and pests should be focused on preventing incidence and severity. Therefore, we must consider some basic aspects and preventive measures in durum wheat management.

▪ **Use resistant varieties to certain diseases:**, INIA has incorporated this varietal resistance to durum wheat varieties, which makes possible to reduce considerably fungicide applications and, in many cases, not to use foliar fungicides.

▪ **Monitoring of climatic conditions** pathogens are favored under certain conditions, high temperatures combined with high humidity during cultivation period, may be a determining factor for foliar development and root diseases. Therefore, knowing developing conditions of pathogens can be decisive in decision making.

▪ **Durum wheat growing stages identification** will allow farmers to keep manage and control efficiently. This way, if the disease occurs, it can be controlled in its initial state.

▪ **Planning a strategy of crop rotation and stubble management**, reduces the risk of attack and dissemination of numerous diseases and pests, whose causal agents survive on crop residues and soil. Additionally, it reduces the pressure of weeds and insects, in most cases improves the biological activity and allows to generate balance in soil fertility.

▪ **Avoid wheat monoculture or rotation with other gramineous**, allowing to achieve a lower incidence of root diseases and lower pressure of foliar pathogens throughout development.

Among the pathologies that may affect durum wheat cultivation in Chile, we determine the following

1. POWDERY MILDEW

Caused by *Blumeria graminis*

Symptoms
White fluffy, cottony appearance.

Chemical control
Application since stem stage. Fungicide with active ingredient stem elongation stage Tebuconazole and epoxyconazole.

Favorable environment
Springs with high relative humidity and T° 15-22°C. High population of plants due to seed dose greater than 240 Kg ha-1.

Preventive control
Use of certificated INIA seed, moderate resistance varieties.

2. LEAF RUST

Caused by *Puccinia triticina*

Symptoms
Orange-brown pustules that are raised above the leaf surface.

Chemical control
Fungicide with active ingredient Tebuconazole and epoxyconazole or strobilurins.

Favorable environment
Three hours of wet foliage and T° of 20°C. Appears in October / November

Preventive control
Use of INIA's certified seed, moderate resistance varieties.

3. SEPTORIA LEAF BLOTCH

Caused by *Septoria tritici*

Symptoms
Pale grey to dark brown blotches on the leaves and to a lesser extent stems and heads.

Chemical control
Fungicide with active ingredient Tebuconazole and epoxyconazole, azoxystrobin, triamenol krexoxim methyl.

Favorable environment
Very early sowings and very cold rainy winters.

Preventive control
Use of INIA's certified seed, they present resistance. Recommended sowing period.

4.

TAKE-ALL

Caused by *Gaeumannomyces graminis var. tritici*

Symptoms
Emergence of uneven and chlorotic plants, necrotic roots, bleached and vain spikes.

Chemical control
Disinfect seeds with fungicides whose active ingredient is fluquinconazole or triticonazole.

Favorable environment
Wheat monoculture, previous cultivation of natural pasture, high population of grass weeds.

Preventive control
Residue management, good rotation for instance with canola, lupine, potato or sugar beet, among others.

5.

BARLEY YELLOW DWARF

Caused by *Barley yellow dwarf virus*

Symptoms
Affected plants show a yellowing or reddening of leaves, stunting, an upright posture of thickened stiff leaves. The heads of affected plants tend to remain erect and become black and discoloured.

Chemical control
Insecticide like Imidacloprid.

Favorable environment
Cold weather, presence of grass stubble which hosts of insects that transmit the virus.

Preventive control
Use of certified seed, natural enemies such as syrphids, lady bugs.

E. IRRIGATION

Irrigation is an essential issue in crop management. Within good agricultural practices it is very important to identify the origin of used water and to determine the possibility of contamination produced by external agents such as pesticides. Therefore, it is necessary to perform a water analysis once a year, in order to determine that there is concordance with conditions of the Official Chilean Standard Water Quality Requirements for Different Uses "(NCh 1333 - 1978, Mod. .1987).

There are five growing stages in durum wheat, in which the crop demands moisture in the soil, and these are:

- **Sowing**, Good soil moisture ensures good germination.
- **Tillering**, Lack of water will damage the entire foliar mass development of the crop, less stems are finally translated into fewer spikes per m2, reflecting a lower final grain yield.
- **Stem elongation** Spike has all spikelets formed at this point, reason why it is essential to avoid any environmental stress and lack of water.
- **Flowering:** It is the most sensitive since pollination and fertilization occurs.
- **Grain formation:** Deficit of water in this period limit a good filling of grains, obtaining deformed and sucked grains, with no commercial value.

In general, the demands of water increases from October to December, due to the fast development of plants that coincides with a greater evapotranspiration, as a result of temperatures increase, corresponding to the spring season, precisely when the stem elongation, flowering and grain formation develop. **(Figure 4)**.

As seen in **Figura 4**, demand for water reaches its peak during the milky stage, after which it experiences drop and therefore, the application of risks after the mentioned stage would not be justified.

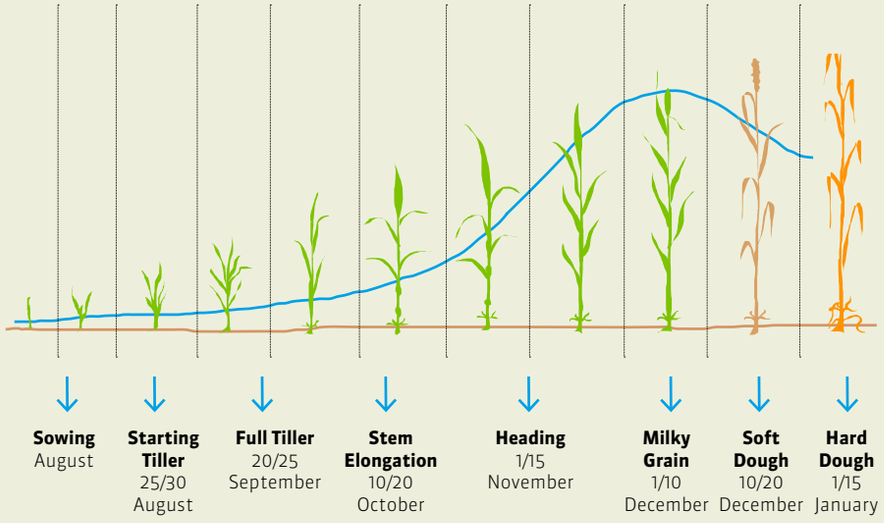
Regarding irrigation, there are two key recommendations:

Avoid waterlogging, since they suffocate plants, increasing the probability of diseases, lower industrial quality and grain yield. **Stop irrigation** when the **grain** is in **soft dough** stage. This way appearance of **"Black point"** (Alternaria spp.) is avoid, which may cause rejection at grain delivery of grain at mill and the increase of yellow berry grain.

CHECK POINT Nº5

irrigation — ***Available water during sowing, tillering, stem elongation, flowering and grain filling. Finish irrigations in soft dough grain stage.***

Figure 4. Water need in each growing stage of wheat culture. Adapted from Mellado, 2007.



Daily water demand average of wheat in Region VIII							
Real evapotranspiration (mm day-1)	0.5	1.14	1.96	3.9	5.8	4.7	4.27
Evapotranspirated water (mm3 day-1 ha-1)	0.5	1.14	1.96	3.9	5.8	4.7	4.27

Another important point to verify in durum wheat crop is the number of spikes per m2. It is estimated that, in order to obtain good grain yield and to avoid diseases due to excess moisture, one must have 500 to 600 spikes per m-2 (Fundación Chile, 2011).

$$\frac{\textit{Spike number per lineal meter}}{\textit{Distance among rows}} * 100 = \textit{Spikes per m2}$$

G. HARVEST

When our crop is practically dry, we must ensure that it ends well and harvest with the corresponding humidity to obtain the maximum industrial performance.

To determine the proper harvest moment, we must check grain humidity. Optimal recommended humidity to harvest is from 15% to 14%, since humidity lower than 14% cause grain losses and broken grains by the machine during this labor.

However, besides grain moisture there are other factors to take into consideration both when making the threshing and once this is done.

During threshing, we must ensure proper calibration of the combine, in good shape to work and avoid losses from damage to the grains.

It is advisable to check the harvest conditions during the day, morning, noon and afternoon, since moisture conditions of plants and grain change. This may generate harvest losses, as an increased number of broken grains because of its humidity lowering.

Use clean bags, free of any factor that may contaminate the crop such as fertilizers and / or chemicals.

Always protect safety conditions for both workers and personnel operating machinery involved in this task.

CHECK POINT Nº6

harvest

Clean harvester machine, free of previous harvest seeds, free of weed seeds and any impurities that could contaminate our grain.
Properly calibrated harvester machine, to avoid grain losses.

H. STORAGE

The designated place to storage our harvest must provide proper humidity, temperature and ventilation conditions in order to avoid grain damage.

Before storage of grain make sure the place is clean, pest free, such as rodents and / or insects that can cause losses.

Make sure the staff in charge of carrying the cleaning out and disinfection of the place apply the necessary product under safety conditions specially recommended for that agent.

CHECK POINT Nº7

harvested grain storage

Clean warehouse, pest free, with no grains from previous harvests nor impurities which could contaminate our grain, with good ventilation and adequate temperature.

I. TRANSPORTATION

When planning crop transportation to the storage place, make sure the truck to be used is clean, garbage free and / or other contaminant that may affect the grain.

At this point, security of both consignment and staff involved in this task is very important. Therefore, verify that the truck complies with required standards by pertinent authorities as well as that the driver has appropriate training and required license to perform this task.

CHECK POINT Nº8

harvest grain transportation

A clean body truck, pest free, grains from previous harvests or any impurities that may contaminate our grain. Properly updated license and registration of both, driver and truck with required authorizations to perform this task.

J. DURUM WHEAT QUALITY

The good practices mentioned in this handbook are intended to get farmers to finally meet all the evaluation requirements of crop receptor companies adequately.

Harvest evaluations are based on pasta industry requirements according to 8 parameters. Table 10 shows each parameter, such us demanded requirement level and the associated GAP to meet these requirements.

Table 10. Pasta industry requirements and associated GAP to obtain them.

Parameter	Pasta industry requirement level	Associated GAP
Grain humidity at harvest	14,5%	Verify harvest conditions as the day progresses. Adjust combine machine. Cut irrigation during Soft dough grain.
Hectolitre weight	Higher than 82	Appropriate application of nitrogenous fertilization in sowing stages (20U), tillering (90U) and stem elongation (90U). Avoid water stress in plants by ensuring adequate soil moisture at planting, tillering, stem elongation, flowering and grain formation stages.
Impurity	Lower than 5%	Clean machine thoroughly before harvesting. Perform a correct weed control before and after sowing. Transport harvested grain in clean and adequate trucks. Use clean free of any contaminant's bags during sowing.
Presence of sucked and chopped grain	2%	Harvest with proper grain moisture. Calibrate the combine adequately.
Protein percentage	Higher than 11%	Adequate application of nitrogenous fertilization in sowing stages (20U), tillering (90U) and stem elongation (90U).
Vitreousness	75%	Stop irrigations in Soft dough stage. Adequate application of nitrogenous fertilization in sowing stages (20U), tillering (90U) and stem elongation (90U).
Black point	Lower than 8%	

4.

GENERAL RECOMMENDATIONS FOR USE AND STORAGE OF PHYTOSANITARY PRODUCTS

CONSTANT MONITORING OF DISEASES AND PESTS, FROM EARLY STAGES OF THE DEVELOPMENT OF THE PLANT.

▪ **Acquire phytosanitary products in established** , and registered institutions in Chile, authorized by SAG, which may be verified by reviewing product label.

▪ **Use recommendation** of a product for the species, which may be verified in product label, as well as use instructions.

▪ **Transpportation** of phytosanitary products to the farm must be carried out in a vehicle with a separated cab from the loading area.

▪ **Record application days** on the farm and used products data.

▪ Place or **exclusive warehouse for storage of Phytosanitary products** with ventilation and / or permanent isolation, away from food, seeds, fodder and water sources. Taking necessary precautions to keep the place in good condition and protected from weather.

▪ The place must remain locked by authorized personnel and must have signage, inside and outside the place, indicating the corresponding warnings including a fire extinguisher in good shape.

▪ **Keep products tidy,** in vertical position with their labels and in their original containers in good condition, since it is forbidden to re-pack or divide the product.

▪ **Maintain registry** , that allows to identify products, handled inventory and to dispose expired products. Expired phytosanitary products according to its label must be kept apart from other products until they are removed from the facilities.

▪ **Keep an exclusive extinguisher with an emergency plan** indicating worker what to do in case of poisoning, fire, product spills or others, either on the farm or in the warehouse and / or dosage sectors.

A. APLICATION OF PHYTOSANITARY PRODUCTS

Verify proper equipment operation and adequate weather conditions in which the application is carried out.

Verify label and safety sheets when using personal protection elements to perform application, such as gloves, face shields, glasses, shoes and clothing. Additionally, person in charge must have an authorized credential by the SAG that qualifies him to perform application of the product.

- **Take precautions to avoid drift of product** to populated areas and remainder must be stored duly labeled in the warehouse.

- **Do not use the same phytosanitary product successively** and never more than twice in the same crop.

- **Wash personal protection equipment thoroughly,** which should not be placed in the same warehouse where phytosanitary products are stored. Used spray equipment and its nozzles should be rinsed at least twice.

CHECK POINT Nº9

Use and storage of phytosanitary products

Considerate all previous points from the acquisition of the product in established institutions, its transport, storage in suitable warehouses, and the application taking proper precautions for assuring safety and health of staff.

B. PESTICIDE WASTE MANAGEMENT

Pesticide containers must not be burned, buried or reused, but must be triple-washed and managed under an approved disposal program by the health authority. The triple wash procedure consists of:

Fill a quarter of the container with clean water, cover it and shake for 30 seconds, to dispose contents into the application tank. This same procedure should be repeated three times, then the containers should be drilled in the bottom, to avoid reuse and the water used for cleaning should be diluted.

Subsequently, they must be stored in an exclusive and closed place for it, until their transfer to authorized collection areas in the region. Requirements container reception at collection sites are : triple washed container, unused, without lid, dry and liquid or solid waste free. Otherwise, if described features are not complied, they will be rejected.

How wheat defects affect pasta?

Black points
It refers to any grain that presents a dark brown or black spot, covering 50% of the germ or more, or if spot is in another sector of the grain. This defect manifests as freckles in semolina or pasta.
- Greater presence of black spots in semolina and pasta.
- Less color in semolina and pasta.
- Probability of the presence of mycotoxins (alternariol).

Frozen and immature grains
Those that present discoloration and waxy appearance sometimes, immature grains are those that do not reach biological maturity, greenish appearance.
- Reduced semolina production.
- Low coloration of semolina and pasta.
- Low production of quintals per hectare.

Grain with yellow berry
Those, which present equal or more than 50% of the starchy grain.
- Reduce the color of the semolina and pasta.
- Low semolina production.
- Decreases Hectoliter Weight.
- Lowers the value of the protein.

Sprouted grains
Those that present its germ open or with signs of germination.
- Reduces quality of protein (gluten).
- Affects texture of cooked pasta (soft pasta).

Broken and sucked grains
Those grains that pass through a 2.2 mm wide by 20 mm long sieve and are retained by the mesh 1.7 by 9.5 mm wide.
- Low production of semolina
- Low hectoliter weight
- Affects the color of the pasta.
- Probability of bacteria, fungi or mycotoxins presence.

Impurities and stones or lumps
Set of grains and foreign materials that do not correspond to wheat, such as wheat packaging, another species seeds, stones, lumps, sand. They generate traces of minerals during milling, causing problems with innocuousness of the final product.

Why dry wheat is important?

- **It decreases probability of fungi and mold development. Less presence of toxins.**
- **Allows safe storage for longer periods.**
- **Reduces drying costs.**
- **Increases semolina production and kilos of wheat per hectare.**

5.

CHECK POINTS SUMMARY

CONTROL POINTS AND THEIR CONSIDERATIONS CORRESPONDE TO KEY STAGES OF CULTIVATION AND POST HARVEST MANAGEMENT. ABOVE POINTS ALLOW GRADUAL IMPLEMENTATION AND MAINTANANCE OF GOOD AGRICULTURAL PRACTICES IN DURUM WHEAT PRODUCTION. THEY WILL HELP TO ACHIEVE OPTIMAL GRAIN YIELD AND TO OBTAIN THE QUALITY AS WELL THIS INDUSTRY EXPECTS.

*	CHECK POINT	CONSIDERATIONS	2017-2018	2018-2019	2019-2020
Nº1	**pH level**	*is very important to carry out soil analysis before durum wheat planting, since it has special requirements for some microelements and levels of acidity.*			
Nº2	**planting date**	*According to INIA variety recommendation in each zone.*			
Nº3	**clean and calibrated machine**	*Sowing depth no more than 5 cm.*			
Nº4	**plant population in two growing stages**	*2 leaf wheat. Plant population from 200 to 350 plants m2 tillering 500-650 tillers m2.*			
Nº5	**irrigation**	*Available water during sowing stages, start of tillering, stem elongation stage, flowering and grain formation. Stop irrigations in soft dough grain.*			
Nº6	**harvest**	*Clean harvester machine, seed free from the previous harvest, weed seeds and any impurities that could contaminate the grain. Well calibrated harvester machine, avoiding grain losses.*			
Nº7	**harvested grain storage**	*Clean warehouse, pest free, grain from previous harvests and any impurities that could contaminate the grains, adequate temperature and ventilation.*			
Nº8	**harvested grain transportation**	*Clean body truck, pest free, grains from previous harvests and any impurities that could contaminate our grain. Truck and driver updated documentation with respective permits to carry out this task.*			
Nº9	**use and storage of phytosanitary products**	*Consider all the mentioned points from product acquisition in established institutions, transport and storage in suitable warehouses and application of it taking care of health and safety of staff in charge.*			

Our producers have trained and grown together with us

Because we have been knowing Chile's mothers for more than a hundred years, we are sure that they all have in common the affection and caring of feeding their families the best way: with quality and the best flavor. That is why Lucchetti is Mom's pasta.

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