COMMERCIAL MAIZE PRODUCTION

FIELD GUIDE

by

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Foreword by A J Masuka

ZIMBABWE AGRICULTURAL SOCIETY

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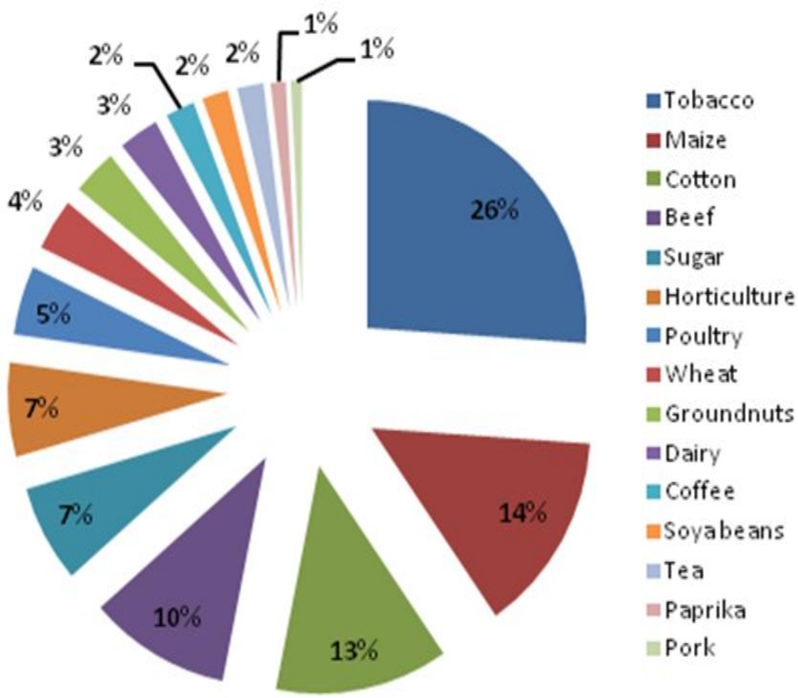
Foreword

1. *Introduction*

Increasing maize productivity is the only real and sustainable basis for achieving food security in Zimbabwe. The productivity strategic thrust will enable towards the attainment of national food security while generating surplus for the export market. Maize,in addition to being a staple food crop for Zimbabwe, contributes between 14 and 20% to the agriculture Gross Domestic Product, which has a weight of 15-20% on the national GDP. Additionally, agriculture supports employment for about 65% of the population directly and many othersindirectly, both upstream and downstream. Agriculture supplies about 60% of industry raw materials inputs, while consuming up to 40% of industry output. These value chain linkages fundamentally make agriculture sustained, in turn industry, an inevitable focus for policy and government and private sector efforts at increasing economic activity in the country.



Source: Ministry Agricultural Mechanisation and Irrigation Development Crop Assessment Reports (2016)

Successful agricultural production is anchored on three major pillars,dubbed the 'trinity loop' which involve:

1. Germplasm (seed varieties);
2. Resources (financial and non-financial) and;
3. Knowledge (training and extension).

2. Critical Success Factors

2.1. Germplasm

In Zimbabwe we have several very high yielding conventionally bred maize hybrids. These hybrids combine high yielding ability with other complementary agronomic traits such as good standability, disease and heat tolerance, fast dry down rate, good Water Use Efficiency (WUE), and high Fertilizer Use Efficiency (FUE). The complementary agronomic traits are agronomic excellence and grower focus and consistence. The combination of high yields and good complementary traits in agricultural systems is rare.

Generally,Zimbabwean maize hybrid varieties have the genetic potentialyield to achieve at least six tonnes per hectare under dry-land cropping conditions.However, some varieties have the genetic potential toachieve 19t/hectare as Agricultural Research Trust trial results,have shown,under irrigated conditions. In fact more than 35 farmers who participated in the Seed Co 11 Ton Plus Club, achieved between 11 and 22 tons per Ha. Under high yield potential conditions,good varietal choice contributes up toother 50% to the success of the farmer and the 50% is based on the farmer'sgood agricultural practices.Thenational maize average yield is below one tonne per hectare.These low yields are reflective of poor agronomic practices, which fortunately can be rectified through practical farmer training, provision of additional technical back up and rejuvenating and improving extension services and availing timely and affordable inputs and finance.

Zimbabwe was probably the second country after the United States of America to use hybrid maize as commercial production in 1950. The advantages of using hybrid seed are clearly discernable (Fig 1).

Fig 1: Hybrid maize variety

Hybrid Power: Cob from hybrid vs retained seed

Hybrid maize is used in over 80% of maize production in Zimbabwe, although with climate change, there have been increasing support for the use of open pollinated varieties. The debate and discussion between generally low yields annually compared to periodic bumper harvest will continue into the future.

Fig 2: Hybrid maize

Capitalise on Hybrid potential (Fig 2)

2.2.Resources

Zimbabwe is endowed with conducive climatic conditions for maize production. The high literacy rate in Zimbabwe should improve agricultural productivity and food self-sufficiency. Zimbabwe's water bodies have a capacity to irrigate more than 2million hectare. Currently the irrigated land is over 100 000 hectares. Finance and inputs generally hamper production, however recent support programmes by government have closed the finance gap.

2.3.Knowledge and Extension

Agricultural extension plays a central role in promoting productivity and food security through timing farmers on good agronomic practices. There are relatively well advanced and comprehensive extension services in Zimbabwe, technically competent but with very limited mobility.Consequently, extension services cannot reach out to all needy farmers. There is a huge gap between research station yields and productivity levels of farmers. This presents an urgent challenge for government, extension services, financiers and farmers.

2.3.1. Tools for Extension

Accurate and practical information on what to do, when and how to do can be obtained through visits to other farmers, focused discussion groups, crop ‘‘circus’’ meetings, farmer syndicates and field days.Competitions,including the recently introduced maize ‘‘Ten tonne Club’’and thehigh achievers competitions in the communal sectorshould also be re-introduced to motivate higher levels of productivity. Higher productivity reduces the production cost per tonne, leading to greater profitability for farmers.

3. Good Agronomic Practices

Good agronomy contributes at least 50% to the gross income. Success favours the prepared farmer. As a guide, there are six planning phases, ‘‘covenants’’, to ensure farmer success. The six step planning process comprises:

Step 1: Identifying and setting farm and household goals,

Step 2: Conducting a resource inventory (availability, quantities and quality), Step 3: Organising resources into whole farm plan,

Step 4: Estimating costs and returns (enterprise budgeting),

Step 5: Organising enterprise budgets into whole farm budget and

Step 6: Implementation.

MAIZE COSTS OF PRODUCTION

Inputs	Rate/ha	Input Detail	Unit Cost	Cost/HA
Seed	25	kg maize seed	3	**75.00**
Fertiliser	250	kg D 14:28:14	0.64	160.00
	400	kg AN 34.5%	0.64	256.00
	1000	kg Lime	0.1	100.00
				516.00
Herbicides	1.5	L Atrazine	6.00	9.00
	0.5	l Diplus	9	4.70
	45	g nicosulfuron	1	25.20
				38.90
Insecticides	4	kg Thiodan granules	9.6	38.40
	0.2	l lambda	10	2.00
				40.40
Labour permanent	10	Labour days	3.5	35.00
- seasonal	20	Labour days	3.50	70.00
				105.00
Tractor operations	20	litres	3.60	95.00
Harvesting	20	litres	3.60	143.00
Transport	10	litres	3.60	36.00
				274.00
Total Variable Cost				**1,049.30**
Yield	8	t/ha	390	

Gross income	390	per tonne	**3,120.00**
Gross margin before overheads			**2,070.70**
Return per $TVC			**1.97**

Gross margin is calculated before overheads, cost of borrowing and other miscellaneous costs

Fertiliser and pesticide options are not limited to the ones in the Gross Margin guide, there are several options on the market. Contact your fertiliser or chemical suppliers for more.

3.1.Land Preparation

The most suitable soils for maize production are those with a good effective depth, favourable morphological properties, good internal drainage, an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favourable. The purpose of soil tillage is to maintain the existing structure of soil or to improve the structure of poorly structured soils.Land preparation and soil condition should address the threecritical soil aspects/properties, (Fig 3), physical, chemical and biological component.

3.1.1. Physical Properties

Physical aspects are concerned with the structure and texture of the soil. Farmers should prepare a fine tilth to facilitate good seed-soil contact to ensure good germination and an even stand. Leaving stover improves the soil physical structure with time. Lime and gypsum applications also improve the soil structure but their applications and application rates have to be determined by soil analysis and recommendations from the analysis specific to the land. Lime and gypsum improve soil physical structure by reducing soil crusting.This promotes better crop emergence and ultimately results in a better crop stand. Optimum populationsare key in attaining higher yields in all crops.The soil should be deep and well drained with no compacted layers in the top 30cm (the root zone).

Lime is required to 'sweeten' acidic soils. Gypsum improves the soil physical structure,removinghard setting cloudiness andremoving surface crusting and poor soil workability.

3.1.2. Chemical properties

Chemical properties include:

1. pH.
2. Salinity (EC)
3. Cation exchange capacity (CEC)
4. Organic matter
5. C:N ratio (Carbon to Nitrogen)

The ideal soil pH for maize production is 5.5-5.8 on the water scale.Lime should always be incorporated into the top 15-30cm zone of the soil because of its poor mobility. Only a soil analysis can reveal the required macro-and micro nutrients required to successfully grow a maize crop.

3.1.3. BiologicalProperties

Crop residues improve the biological, physical and chemical properties of the soil. The soil harbours beneficial bacterial, fungal and other microorganisms which function by decomposing organic matter and trapping atmospheric nitrogen. This property should be well maintained by liming. The emphasis onconservation agriculture and climate smart agriculture should assist in restoring the organic matter content of lands. Maintenance of soil pH at recommended levels also improves biological properties.

3.1.4. Liming Benefits

Liming improves Fertilizer Use Efficiency (FUE) by crops. Use of fertilizer alone without lime results in poor fertilizer uptake and reduces the economic benefit of using fertilizer. In economic terms, lime enables growers to get the best Return on Investment (ROI) on fertilizers. Liming, generally, improves the soil structure and nutrient availability and ultimately crop productivity. Liming also provides some plant nutrients such as calcium or magnesium and carbon, sometimes termed ‘complementary benefits’ of liming. Lime reduces availability of toxic elements in the soil such as aluminium and manganese. This results in improved root development and ultimately nutrient uptake.Some herbicides and soil-based chemicals will not work efficiently in low pH soils, liming soils enhances the efficacy of some herbicides especially pre-emergent herbicides.

Table 1: A Guide to Liming

Soil type	**Lime rates to raise by 0.1 pH units**
Sandy soils	100kg/0.1 pH units
Sandy Loamy soils	120kg/0.1 pH units
Clay soils	200kg/0.1 pH units

The bulk nature of lime limits its use in many circumstances. However, there are newer technologies that ensure the usage of only small amounts of organic enhancements with major pH effect and release of calcium. A soil analysis should reveal whether lime (Calcium Carbonate) or (Magnesium Carbonate) should be applied at the required quantities.

Fig 3: Lime application

3.2.Mechanisation

Mechanisation facilitates work on a bigger scale. Appropriate mechanisation improves production, reduces costs/output in the long run, maximises efficiency and optimises yields. Tractors, harvesters, tractor-drawn equipment, storage silos, driers and irrigation are among critical resources a commercial farmer should endeavour to acquire or make arrangements to have readily available for use when required. Equipment hire services are now available in many parts of the agricultural belt, so farmers are encouraged to plan early and hire appropriate tillage equipment.

3.2.1. Irrigation

Irrigation is fundamental as it improves farm productivity on three fronts:

1. enables early summer crop establishment in October to take advantage of the high heat units (HUs)
2. enables supplementary irrigation, when required during the critical crop growth stagesthat usually coincide with the mid-season dry spell and;
3. facilitates double-cropping with summer and winter cropping.

The use of moisture gauges, evaporation pans and other methods in irrigation scheduling is recommended.

3.3.Crop Establishment

Crop establishment is a function of the optimum population densities which maybe variety-dependant, for example, 50 000 to 55 000 plants per hectare for the late maturing hybrid varieties in high potential or irrigated areas or 37 000 to 44 000 in low potential areas, good head start (early vigour)[weed free for the first 8-10 weeks of the crop cycle] andadequate depth of planting (3.5cm when planting in cool moist soil and 5cm when dry planting). Some of the more salient crop establishment parameters are indicated in Table 2.

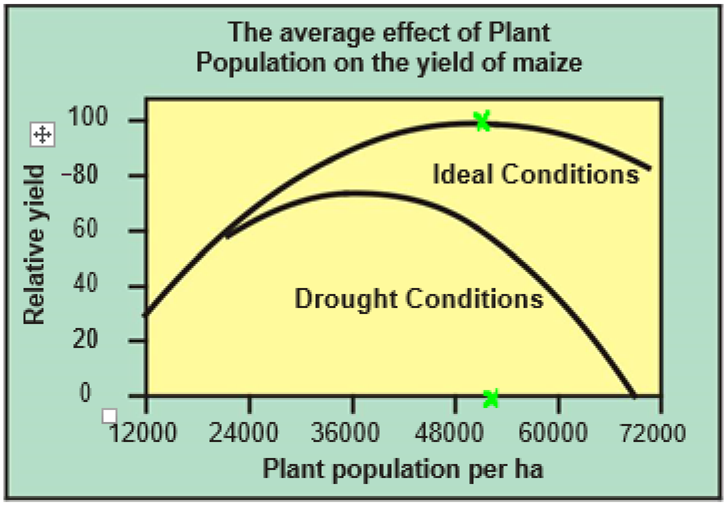
Table 2: Crop Establishment Parameters

Aspect of crop establishment	**Recommendations**	**Remarks**
Population density	50 000 to 55000 in high potential/irrigated environments and 37 000 to 44 000 in low potential areas	Spacing (90cm x 20cm) or 75cm x 25cm and 90 cm x 30 cm
Planting depth	3.5-5cm	3.5cm for moist soil planting; 5cm for dry planting
Basal fertiliser	400kg/ha/250kg/ha double D	Has to be determined by soil analysis results. To be applied at or before planting
Weed	Ensure a weed free crop by making use of pre and post-emergence herbicides	Mix compatible chemicals for wider weed spectrum coverage
Early pest control (cutworm)/fall army worm	Mix lambda with the pre-emergence herbicides for cutworm control	Apply chemicals and scout fields for fall army worm

	Lambda, Carbaryl and Emamectin Benzoate can be used for fall army worm control	
Time of planting	Plant when 30mm (first effective rains)are received within 3 days	Dry planting is also encouraged but the depth should be about 5cm. Plant anyway on the 20th of November onwards with or without rains
Placement of the seed relative to fertilizer	Basal must be placed during or before planting. Banding is the best option in commercial setups Broadcasting and discing under is another option	Done concurrently by planters at planting or broadcasted before planting

Figure 4 shows the dramatic effect of plant population on the relative yield potential of a maize crop.

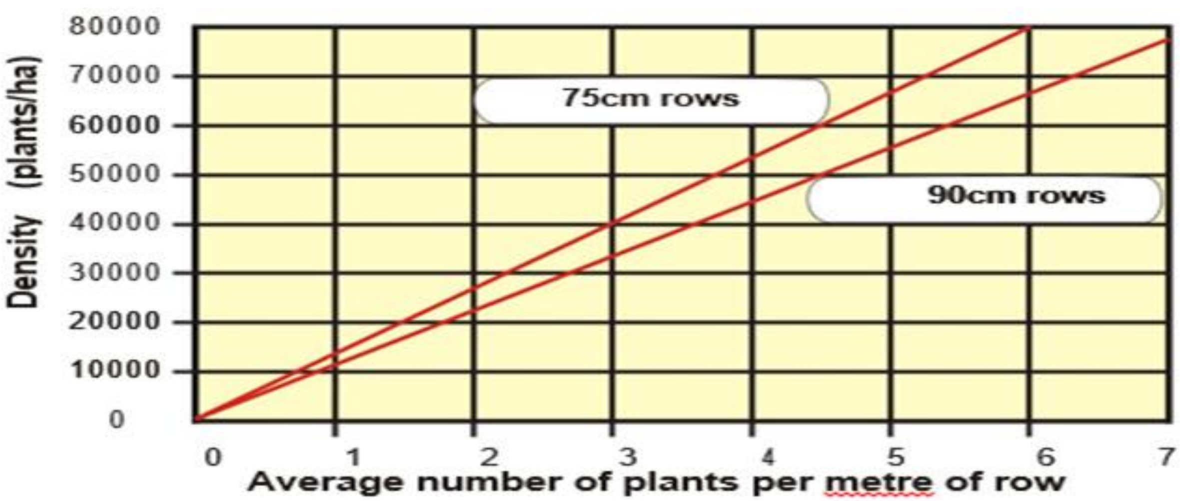
Fig 4: Average effect of population density on maize grain yield



Source: Research data in Seed Co Agronomy Manual

The grower should endeavour to plant at these optimum plant densities per hectare for each variety.The plant population can also be estimated from the number of plants per metre of row (Fig 5). However, at this stage, the adjustment to correct density per hectare may no longer be practically and economically possible.

Fig 5: Simple method to determine the plant population of maize from the average number of plants per meter of row



General guide to spacing for optimum population densities

Source: SeedCo Agronomy Manual

3.4.Weed control

Weeds have a dramatic effect on yields (Fig 6). The field should be free of weeds during the first six to eight weeks after planting, because weeds compete vigorously with the crop for nutrients, light and water during this period. However, it is advisable to maintain a weed free maize field throughout the growing season. The annual yield loss in maize as a result of weeds at a national level is substantial.

Generally failure to control weeds during the first five weeks of the crop cycle, leads to a 50% yield reduction. Weeds should not be allowed to seed. This will increase the weed seed bank and result in increased future weed control costs.

Fig 6: Weed free crop stand at maturity

A weed infested maize field (uncontrolled)

A weed free maize crop (controlled)

There are more than 20 herbicides registered for use on maize in Zimbabwe. The vast majority of these can be sprayed over the maize crop after emergence (Table 3).The correct usage of herbicides requires determining the correct quantity to apply per area for which the right calibration is required (Table 3).

Table 3: Registered herbicides in Zimbabwe

Herbicide Name	**Active Ingredient**	**Time of application**
Atrazine	Triazine	Pre and Early Post-emergence
Dual	S- Metalachlor 960g/l and 40g/l inert matter	Pre-emergence
Lasso	Alachlor 480g/l. Inert ingredients 520g/l.	Pre-emergence
Bateleur Gold 650EC	Flumetsulam (sulfonanilide), s - metalachlor	Pre-emergence
Stellar Star	Topramezone (pyrasolone)	Post-emergence

	Dicamba (benzoic acid compound)	
Auxo	Tembotrione, BromoxynilOctanoate and Isoxadifen-ethyl safener	Post-emergence
Russel		Pot-emergence
Maximus	Terbuthylazine, Mesotrione and Metalachor	Post-emergence
Rimex		Post-emergence
MCPA	MCPA	Post-emergence
Revolt	Dicamba and Nicosulfuron	Post-emergence
Frontier Optima	Dimethenamid	Pre-emergence
Armadillo	Sulcotrione (triketone), Atrazine (triazine), related triazine	Pre and early Post-emergence
Galago	Mesotrione (triketone) 480g/l	Pre and Post-emergence
Prowl CS	Pendimethalin Chemical group- dinitroaniline	Pre and early Post
Servian	Halosulfuron	Post-emergence (Nutsedge)
Accent	Nicosulfuron	Post-emergence (Shamva)

NB: Chemical options are not limited to the ones mentioned above, there are several options available on the market. Contact you're the chemical suppliers for more options.

3.5.Pest control

An integrated pest management (IPM) strategy employs various methods to protect crops from pests by suppressing the insect population and limiting theeconomic damage to the crop. These methods include chemical, biological and physical control,and to a limited extent, varietal resistance. The major pests on maize and their recommended control measures are shown in (Table 4). The fall armyworm deserves further mention, as a new pest and to demystify current thinking among growers on the difficulty of controlling the pest.

Table 4: Major Pest on maize in Zimbabwe

Problem Pests	Control Options	Comments
 Fall Army Worm	Chemical	(Early scouting and early control makes it easier to manage the pest once establish difficult to eradicate. Always spray around 4 to 6PM and a wetter must always be added to the spray mix
Cutworm 	Chemical	Mix Lambda with pre-emergence herbicides
Maize Stalk Borer 	Chemical and Cultural	Crop rotation is a good cultural control but chemical control is recommended
Termites	Chemical and Cultural	Cultural control entails removing maize leaves in each and placing

		these on the interrow to divert attention from main crop

For termites, diverting attention from the main crop as indicated in (Table 4) can have limited success on large hectrages where the long term cultural option is climate smart agriculture where the termites feed on residues instead of the maize crop. Field scouting is a fundamental aspect of efficient pest management.

Growers should investigate fields to prevent problems and improve productivity. Walking the fields regularly, observing, thinking, inspecting and evaluating facilitate early pest detection and enables quick remedies to be sought. Growers should walk through fields in a random manner, stopping every often to examine the soil, plants and surroundings. Growers should be observant and investigative. At least ten places in the field should be examined when making a general inspection, but if scouting for specific pests it may be necessary to examineup to 100 plants, depending on the pest and the size of field,in a *zig zag* pattern.

Growers should always endeavour to:

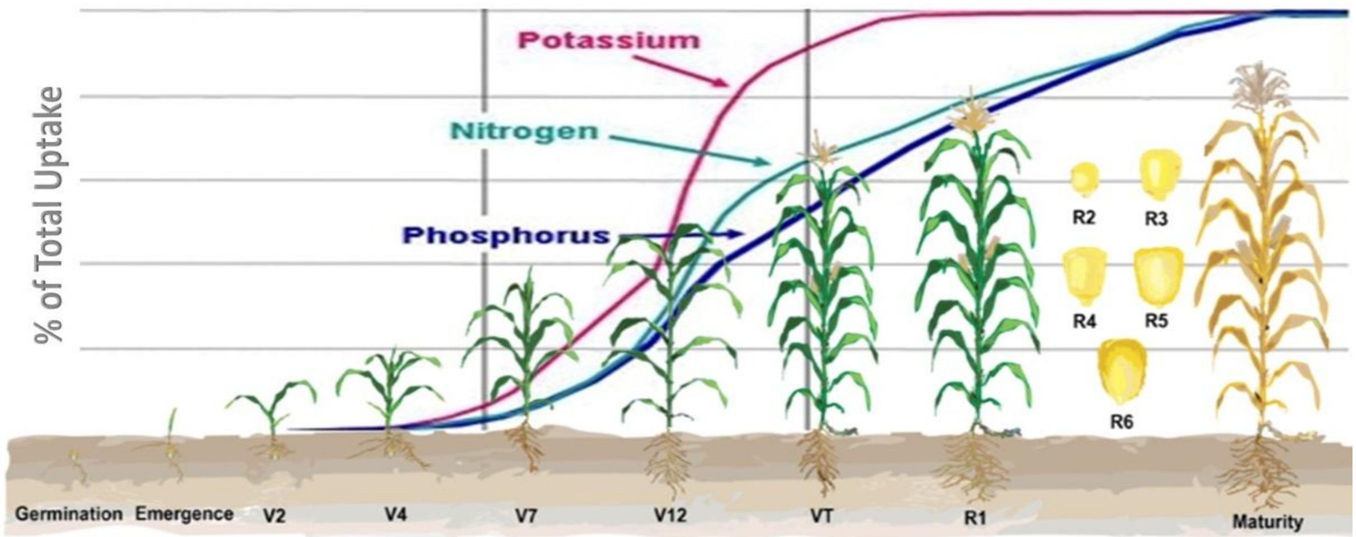
1. have a positive attitude and an open mind
2. try new techniques and technologies.
3. be goal oriented
4. not cut corners
5. be hands-on, scouting fields regularly as ''The best fertilizer is the frequency of the farmer's footmarks in the fields''.
6. start with good fresh seed.
7. preserve the environment by keeping erosion, fertilizer and chemical run off to a minimum to ensure sustainability conservation ofthe natural environment

Calibration of pesticides applicators to ensure the correct amount is used in the least quantities to protect the environment and at the most vulnerable stage of the life cycle of the pest should be aided by regular field scouting.

3.6.Fertiliser Use

Understanding maize growth stages and fertiliser use and timing is important for attaining good yields (Fig 7)

Fig 7: Stages for nutrient use by a maize crop



The three major nutrients for the maize growth's pattern indicate a general and gradual peak at leg v2 when exponential increases in nutrient uptake should take place to meet crop demand. The fertiliser application graph should be based on a soil analysis and on expert recommendations. Many agronomy and fertiliser companies provide this service, in addition to government agencies. However, at the farm level, fertiliser calibration should be done to ensure the recommended amounts are applied in the most cost-efficient manner (Fig 7).

The ''Four Right'' or ''4 R'' system of fertiliser application entails applying fertiliser:

1. from the right source;
2. of the right type;
3. at the right time and;
4. in the right quantity

To produce one tonne of maize a crop requires 23 kg N, 10 kg P and 21 kg K (Table 5).

Table 5: Fertiliser requirements for various maize yield expectations

Nutrient	To produce 1 tonne (kg)	To produce 10 tonnes (kg)
Nitrogen	23	230

To get the amount of nitrogen, always subtract nitrogen amounts contained in the basal to determine top dressing rates (Table 5).

3.6.1. Fertiliser timing

3.6.1.1.Basal Fertilisers

Basal fertiliser must be applied before or at the time of planting, preferably cupped into the planting hole, or applied in a band below and to the side of the seed with a mechanical planter.The various amounts of fertilisers and application rates are indicated in (Table 6).

Phosphate is one of the key elements required for early crop growth. Roots that develop from the seedling and should get early and good contact with the applied phosphate. Unlike potash and nitrogen which have considerable mobility in the soil, phosphate has very limited movement of about 6mm per year,so it must be placed where it is required by the plant.

Table 6: Basal fertiliser types and rates of application

Basal Option	Formulation (N:P:K)	Recommended Rate/ha (kg)
Cereal Blend	6:23:23	350
Double D	14:28:14	250
Compound D	7:14:7	400-500
Maize Blend	6:20:15	350-400
High C (MOP Based)	6:28:23	350

3.6.1.2.Top dressing options

Top dressing should be applied 4 to 8 weeks after emergence from‘‘V4’’ to ‘‘V8’’ stages of growth. Generally,a maize crop uses more than 50% of the nitrogen during this phase and this is the most critical stage of plant nitrogen need and use.

Table 7: Rates of N for various yield options

Top Dressing Option	**N Quantity %**	**Target Yield**	**Recommended Rate/ha (kg)**
AN	34.5	>10	450-500
Urea	46	>10	350-400

Fig 8: fertiliser application by crop and by tractor

3.6.1.3.Top dressing fertiliser placement

Top dressing fertiliser can be broadcast with a vicon spreader in a moist field (Fig 9). The other option is to band the top dressing fertiliser using a fertiliser applicator on the inter-row about 10 cm from the plant row (Fig 10).

Fig 9: Fertiliser broadcasting by vicon

Hand Fertiliser applicator

Fig 10: Fertiliser applicator on the inter-row

3.6.2. Checklist before applying fertilizers

1. Are other agronomic factors (eg. variety, plant protection, water) satisfactory?
2. Are basic requirements of soil fertility fulfilled? (pH, organic matter, soil structure, absence of compacted layers, good drainage and no salinity).
3. Which micro-and macro-nutrients need not be considered in a particular soil? (many soils have adequate Ca, Fe, Mo).
4. Which nutrients need not be considered every year? (e.g. Mg may be supplied in liming material; Zn, B and Cu in long-lasting, slow-acting fertilisers.)
5. What amounts of fertiliser P and K are needed at sowing time? (to be determined by soil analysis or, in well supplied soils, estimated from nutrient removal by crop).
6. What kind and amount of N fertiliser is needed, and when? (either based on expected yield or soil analysis).
7. Which nutrients may have special problems in a soil?
8. What is the best way of applying fertiliser? (banding is usually more efficient than broadcasting, but application depth and placement of fertiliser should relate to root structure).

The ‘‘rule of thumb’’ is that a farmer should not see these deficiency syndromes on his crop (Fig 11)

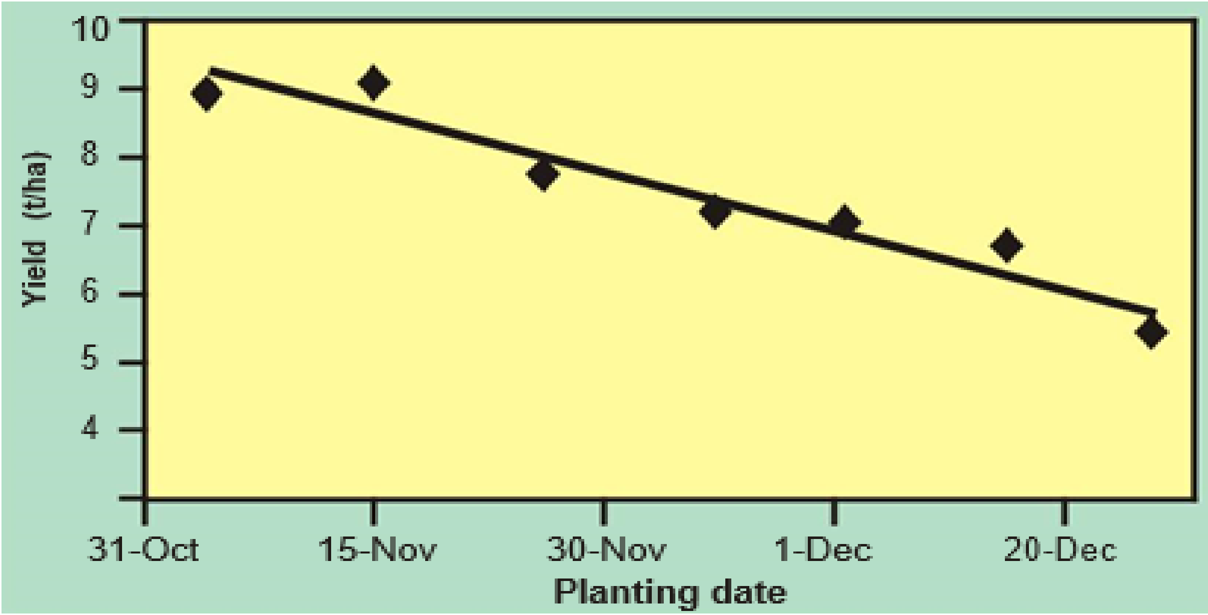
Fig 11: Deficiency symptoms on maize

Symptoms	Deficiency
Symptoms appearing first on younger leaves:	
Mottled yellow-green leaves with yellowish veins	S
Mottled yellow-green leaves with green veins	Fe
Brownish black spots (e.g. on legumes, potatoes)	Mn
Youngest leaf has white tip	Cu
Youngest leaf is brownish or dead (e.g. on beet)	B
Broad bands of bleached, pale tissue	Zn
Symptoms appearing first on older leaves:	
Chlorosis (i.e. yellowing of leaf) starting from leaf tips	N
Necrosis (i.e. death) on leaf margins	K
Chlorosis mainly between veins (which remain green)	Mg
Brownish, greyish, whitish spots (e.g. on cereals)	Mn
Reddish colour on green leaves or stem	P

3.7.Time of Planting

The time of planting has a major effect on the yield of a maize crop. For most crops, there is an optimum time of planting, which depends on the climatic conditions and the time taken by the crop to reach maturity. For a summer crop such as maize, early planting at the beginning of the rainy season (Fig 23) is desirable, as yields decrease with late planting primarily due to decreasing daily Heat Units. It is advisable to always plant with the first effective rains, equivalent to 30mm rainfall in three days. After the first week of November yield loss is 100kg per hectare per each delayed week. Maize growth rate responds well to high daily temperatures experienced in October, November and December. In fact, more than 40% of the HUs are experienced during these three months so it is critical for farmers to plant their crop as early as possible to capitalise on the HUs. Under rainfed situations, after 20 November a farmer is encouraged to dry plant at a depth of about 5 cm to ensure the seed is not spoilt by light showers.

Fig 12: Average effect of planting date on yield of Maize over two seasons



Source: Seed Co Agronomy Manual

3.7.1. Heat Units

Farmers can compute the heat units for their location thus: (Maximum Daily Temperature + Minimum Daily Temperature)/2-Base Temperature = HU

The Base Temperature is usually 10^{o}C.

Temperature is the most important environmental factor influencing the rate of maize crop development.

3.8.Water and Rainfall Requirements

A maize crop requires about 450 to 600 mm of water per season to reach physiological maturity, which is largely acquired from the soil moisture reserves. About 15-20 kg of grain are produced for each millimetre of water consumed, all other factors being constant. At maturity, each plant will have consumed 250 litre of water.

3.9.Preparing to harvest

Farmers should plan and prepare for the harvest in advance and have all logistics in place, especially if the contemplate using the same land for a winter crop. Equipment should be calibrated, packaging/bagging materials and dryers should be in place and ready before the planned harvest response. Check machinery and conduct adjustments before the harvest. Owner's manuals instructions must be followed at all times.

3.10. Checking moisture levels

Harvesting and drying can commence when the crop reaches a moisture level of 20% or less. It makes economic sense to harvest and dry a crop at this moisture level. The optimum storage and acceptable selling moisture level for maize grain is 12.5% and below.

3.11. Hand Harvesting Methods

3.11.1. Bang Board Trailer

This is an option for farmers who cannot access combine harvesters. Cobs are loaded (by throwing) directly into a tractor drawn trailer which is fitted to a bang board. We recommend six rows to be harvested on each side of the trailer at a time. This is because workers become less accurate as the number of rows increase and forward speed is also reduced. The cobs in the two rows straddled by the tractor wheels are harvested first and heaped on the sides and loaded later.

Fig 14: Harvesting by bang board trailer

3.11.2. Drums/Sacks and trailer:

When large harvest gangs are available we recommend the drums and trailer method. Cobs are harvested into a 25 litre container or a 25/50kg empty bag then emptied into a tractor/animal drawn trailer. Larger containers can also be used but two workers may reap into one container. For efficiency, two tractors and three trailers should be ideal if the gang is large. The crop (with husks) is then shelled using a tractor-driven sheller.

3.11.3. Using Sacks only

Some farmers prefer reaping directly into sacks. This system is particularly useful when shelling is done in the field. The cobs are reaped into the sacks by reapers and they are emptied into a tractor-towed sheller. The ratio of reapers to waitersshould be 2: 1. Reaping can be done directly into a towable sheller. However, this has proved to be inefficient in most cases as reapers may fail to match the sheller running rate.

Fig 15: Harvesting by sacks only

Mechanical harvesting

Combine harvesters come in two types: the conventional and: rotary types. A combine harvester performs a number of functions in a single run - cutting the stalks, picking, de-husking, shelling, winnowing, blowing out chaff, cleaning the grain and loading bins/trailers for delivery.

With a combine:

1. The farmer is independent of labour hires and averts double handling,
2. This is a faster rate of harvesting than with hand harvesting, so the method suits large hacterages,
3. The machine chopsstovers for ploughing down and/or planting, and
4. This method works well with bulk handling operations.

However:

1. When there are problems with cob rots, there is no possibility/provision of sorting out the affected cobs,
2. The combine cannot pick up cobs lying on the ground and as a result it will not work efficiently on lodged crops,
3. Steep slopes, small fields and high moisture content of the crop affect the efficiency of the machine, and
4. The combine cannot work well in densely weeded fields and
5. Varieties with good standability and less lodging are recommended for machine harvesting.

What needs to be checked on a combine harvester?

Harvesting losses must not exceed 3% when using a combine harvester, therefore, it is important for farmers to do a 'health check' from 'front to back' using a check-list provided by experts/suppliers. Always target ZERO breakdowns during the harvesting period. A health check is critical and March-April is the right time to do this check. The checklist/inspection points should include: fan belts, bearings (for wheels and shafts), chains, head (check all inspection points), intake auger (check all chains), winnowing fan (which blows the chaff), grain pans/sieves, augers to grain tanks and straw shredders.

Factors that affect combine efficiency and reaping output.

1. Crop moisture levels:-Dry crop and cobs are easier to pick, de-husk and shell. A crop can be harvested at 20% moisture content and below. Moisture levels above 20% can compromise harvester efficiency.
2. Row spacing: Spacing must suit the head spacing and usually ranges from 70-90cm, depending on combine make. When there is no crop uniformity then knocking down will result and may cause harvesting losses and increase the gleaning expenses.
3. Cob placement and standability: A variety with good standability and average cob placement is easily and efficiently harvestable. A lodging crop is difficult to harvest with a combine and can cause harvesting and yield losses. We recommend varieties with good standability which should be planting at recommended population densities. Target to harvest 95% of the crop by a combine harvester.
4. Land terrain: A well prepared and levelled (even) land is easy and less costly to harvest, otherwise speed must be adjusted and rather reduced if the terrain is not even and;
5. Combine, trailer/truck/bin ratio: We recommend a good balance of combine harvesters and trucks in the field. When the combine light shows up, there must be an offloading bin available so that there is no disruption of the harvesting operation.

Gleaning

Field inspection during harvesting should be doneregulary. All knocked down crops and fallen cobs must be picked by the gleaning gang. The collected left overs can be shelled by a sheller or fed into a running combine at the end of each day's work.

3.12. Grain drying

Maize harvested when the moisture content is high will necessitate drying the grain to the optimum moisture level for shelling andstorage. To maximise on land/irrigation utilisation, a farmer may be recommended to harvest a maize crop before reaching the storage moisture level of 12.5%. This will require drying the crop/grain which can be done naturally or artificially. With natural drying, the cobs are left on the plant to dry or reaped and heaped in strips on open dry land/slabs. The cobs can also be reaped and put in cribs and left to dry to the required moisture content. Alternatively, grain is dried in bags, but this tends to be a very slow process. Normally, natural drying is common when the weather is sunny and dry.

With artificial drying, the underlying concept is 'forcing heat through the grain'. The heated air then causes moisture to evaporate from the grain. The rate of drying depends upon the temperature of drying air, velocity of the air through the grain and the uniformity of its distribution in the drying silo/chamber. The maximum temperature of drying air will depend on such factors as the type of crop to be dried, the moisture of the crop and the system of drying being employed.

3.13. On farm maize storage

Grain storage losses can be as high as 25%-30% of the yield largely due to high moisture, pest damage, fungal/bacterial infections and rodent damage. The3 out of 10 bags can be lost due to poor post-harvest losses. In Zimbabwe, many people depend on stored grain for consumption, making it an imperative to equip farmers with information on how best to manage post-harvest losses.

Losses of grain can be quantitative, qualitative or both. The key to successful on-farm storage is to anticipate and prevent potential problems through good in-store management practices which include:

1. Sanitation
2. Use of chemical protectants
3. Inspection and
4. A combination of the above practices.

Farmers should always note that stored grain may deteriorate:

1. if high ambient temperature of grain storage places,
2. if the moisture of the grain is too high,
3. if the grain is diseased,
4. if insects multiply in the stored grain,
5. if rodents are allowed access to the grain and
6. if the grain is stored for a long time.

Maize can be stored as 'bulk' or bagged. The storage facility must be suited to the method of delivery. Bulk stored grain is loaded into bulk trailers/bins using augers. Bagged grain usually requires conveyors or labour for loading.

Bulk storage

There are many methods that can be used for bulk storage, for example in above ground silos, bulk containers or bags stored in the open or in buildings.

The bulk storage method is generally:

1. more economical than bag storage;
2. requires less supervision;
3. reduces labour handling and;
4. is more hygienic than bag storage.

However, bulk storage is generally more costly in terms of capital outlay compared to bagging.

For effective bulk storage:

1. the maize grain must be dry, with less than 13.0% moisture content;
2. the storage facility must be structurally sound and designed for loading and offloading;
3. the storage facility must be weather tight and dry, thermally insulated from the sun‘s radiation and also pest and rodent free;
4. the facility must be convenient for inspection, fumigation and cleaning and;
5. the facility must be provisioned to allow loading (of grain by augers) and offloading of grain (from the field)

3.14. Grain Chemical treatment for long term storage

Maize in storage can be affected by many pests including maize weevil (*Sitophilusspp*), Indian meal month (*Sitrotogacereale*), Flour beetle (*Triboliumcastaneum*), Sawtoothed grain beetle (*Oryzaephilussurinamensis*), Lesser grain borer (*Rhyzoperthadominica*), Larger Grain Borer (*Prostephanus truncates*), Rusty grain beetle and other storage pests. These post-harvest pests can cause substantial yield losses if left uncontrolled.We recommend the use of stored grain chemical protectants. Several chemical options are available on the market.

Growers are advised to always read chemical labels carefully, use safe practices and ware adequate protective gear during application. Everyone should always observe recommended pre-consumption intervals on the grain protectant labels. Storage in bags must be in a well aerated place, above the ground to allow free air circulation.

3.15. Yield forecasting

The following steps should be followedsequentially:

1. inspect the land toensure that the stand is even, standing (not lodging) and does not have many gaps;
2. reap the cobs from a measured 20 square metres. if the rows are at 90cm, then reap 22m row length;
3. shell the cobs, weigh the grain and determine the moisture content using a calibrated moisture meter.
4. do this for three separate samples at widely separate points, at least 50m apart.
5. use theformula to estimate yield thus:

Yield = Mass Grain (Kg) x (100-moisture content)/(100-12.5)x10 000/20

3.16. Moisture testing

To determine grain moisture content, we recommend farmers to take 500g samplesor four randomly selected cobs to any nearest GMB depot/maize off-takers for accurate results. The other guiding method is using varietal dry down rates per week. Maize physiological maturity (black layer stage) is normally reached when moisture is around 30%, there-after each variety has dry down rates which can be used to determine harvesting dates (at 12.5%).

3.17. Hastening drying down

Due to excessive rainy conditions, maize fields can be soggy (excessively wet and soft) and this can slow the dry down rate of maize and some other summer crops. Aeration strips/corridors of four combine swathes (16-20 rows harvested by hand/machine) per say 15ha portions are recommended to improve aeration which assists faster dry down. This facilitatesearly harvest and also timely planting of a winter crop especially wheat which should be planted during the last weeks of April to the end of May for higher yields and better quality. Theaeration corridos are only applicable to a maize crop which has reached physiological maturity of 30% moisture.

Fig 16: Aeration Corridors/Strips to hasten dry down

3.18. Gantt Chart showing GAPs activities and timing of activities

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1. Harvesting and selling (summer crop-irrigated)	■	■										
2. Wheat planting (Irrigated areas)	■	■										
3. Harvesting and marketing (Non irrig.)	■	■	■	■	■	■						
4. Soil sampling and analysis	■	■	■	■	■	■	■					
5. Machinery calibrations (summer preps)	■	■	■	■	■	■						
6. Liming and land preparation	■	■	■	■	■	■	■	■				
7. Input procurement	■	■	■	■	■	■	■	■				
8. Attending field days, shows and crop circus	■	■	■	■	■	■	■	■				
9. Planting and basal dressing (maize)							■	■	■			
10. Weed control (pre-emergent)							■	■	■			
11. Top dressing and post-emergence weed control								■	■	■		

3.18.1. Maize-Wheat Double Cropping

For effective and productive land, labour and equipment use summer and winter cropping are practised in the middle to high veld regions of the country in frost-prone areas. Early maize harvesting facilitated by aeration strips/corridors and grain drying facilities should enable farmers to meet the target of early wheat planting. The maize- wheat double cropping option can take advantage of thecurrently recommended conservation tillage techniques. Wheat generally takes 135 days to reach maturity, so it is important to plant early to harvest around September and before October. Varieties such as Seedco'sSC727 and SC719 havegood dry down rates and are ideal choices for maize-wheat double cropping programmes.

Considerations for successful maize-wheat double cropping would induclude:

1. using an early summer crop to be harvested by 20 April,
2. an early winter crop to harvest by the last week of September/first week of October,
3. drying facilities to harvest a summer maize crop at 20-25% moisture content and plant a winter crop on time,
4. maize varieties with fast dry down rates,
5. select varieties which give a good return and are compatible in double cropping,
6. irrigation availability to establish a summer crop early in October and to supplement water during the mid-season drought and for winter irrigation.

Double cropping soya-bean and wheat is advantageous because the soya-bean varieties available in Zimbabwe are early to medium maturing (120-130 days to physiological maturity) in the high to middle veld regions.

4. *Other Farmer Success Factors*

4.1.Institutional and information Aspect

Information dissemination to farmers,including timely relevant and accurate weather updates, inputs availability, good agronomic practices, efficient produce markets and readily available prices information are crucial for achieving high productivity and profitability on farms.

4.2.Social capital

Membership of farmer organisations and local farming groups is useful in providingcrop productivity information and other information on input prices, labour and economic trends. Through information sharing and access to information on prices, markets, inputs availability, and improved varieties, farmers access critical social capital which for improving their productivity and profitability.

4.3.Value Chain Players

These include agro-input traders, banks, extension staff, seed and fertiliser houses. Their task is to avail inputs, credit, extension services, certified seed and fertilisers, timeously conveniently and at affordable and favourable prices.

4.4.Further Reading

1. Seed Co Agronomy Manual, 2017
2. ART Farm Results (....years).
3. Donald. n. Duvick, 2005 &2013,the contribution of breeding to yield advances in maize, National Academy of Science.