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Phytoremediation of Copper and Cadmium from Water Using Water Hyacinth, *Eichhornia Crassipes*

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Abstract

The present study demonstrated the phytoremediation potential of water hyacinth *Eichhornia crassipes,* for the removal of copper (Cu) and Cadmium (cd). Young plants of equal size were grown in tap water and supplemented with 0.35, 0.70 and 1.05 mg/L of Cu and 0.27, 0.54 and 0.81 mg/L of Cd individually for 25 days. The experiment showed that both Cu and Cd had effects on plant relative growth. The plant at all the concentrations used in the experiment removed approximately more than 90% of Cu and Cd. Removal of metals from water was fast especially in the first five days. The accumulation of Cu and Cd in roots and stems increased with the initial concentration. At all levels the plants accumulated the highest concentration of Cd in roots, while the highest concentration of Cu was accumulated in stems. The biocencentration factor (BCF) of Cu was higher than that of Cd at the same duration, suggesting that the accumulation potential of *Eichhornia crassipes* for Cu was higher than that for Cd and could be used to treat waste-water contaminated with low Cu and Cd accumulations.

Keywords

Copper; Cadmium; Eichhornia Crassipes; Phytoremediation; Water

Introduction

Developing cost effective and environmentally friendly technologies for the remediation of soil and wastewater polluted with toxic substances is a topic of global interest. The value of metal accumulating plants to wetland remediation has been recently realized (Black, 1995, Zayed et al 1998, Sadowsky, 1999). This capability is useful in removing toxic heavy metals and trace elements from contaminated soil and water in a process referred to as phytoremediation. The focus on water hyacinth as a key step in wastewater recycling is due to the fact that it forms the central unit of a recycling engine driven by photosynthesis and therefore the process is sustainable, energy efficient and cost efficient under a wide variety of rural and urban conditions (Gijen *et al*, 2000). Heavy metal ions such as Cu2+, Zn2+, Fe2+ are essential micronutrients for plant metabolism but when present in excess they can become extremely toxic (Williams *et al*, 2000). Cadmium has been recognized for its negative effect on the environment where it accumulates throughout the food chain posing a serious threat to human health (APHA *et al*, 1998). Cd pollution has also induced extremely severe effects on plants (Baszynski, 1986). Studies had been done in investigating the capabilities of some macrophytes to remove different concentrations of heavy metals (Maine *et al* 2001, Maine *et al* 2004 Skinner et al 2007), in the role as biomonitors of environmental metal levels (Mishra *et al*, 2007) and in their ability as biological filters of the aquatic environment (Upadhaya *et al* 2007). It is evident that there is an immense scope to explore the potentialities of aquatic plants for the removal of heavy metals from the metal contaminated wastewater. Therefore, the present investigation was carried out to study the phytoremediation of Cu and Cd by water hyacinth *Eichhornia crassipes.*

Materials and methods

Two experiments were conducted from 5th Nov.'07 to 31st March 08. The first experiment was conducted with copper while the second experiment was done with cadmium. Water hyacinth plants were collected from a pond in Bhubaneswar. After collection, the plants were thoroughly washed to remove all the adhered soil particles.

Experimental Set up

For each experiment, twelve buckets were taken and filled with 15 litres of water. The water taken had the pH of 6.7, alkalinity as CaCO3 30 mg/L, conductivity 0.245 mmho/cm. Almost same sizes of water hyacinth plants were kept in ten buckets, and one bucket was kept without the plant. One bucket was maintained with only metal dissolved in water. The plants were kept under natural sunlight for one week to let them adapt to the new environment.

A stock solution (1000 mg/L each of Cu and Cd) was prepared in distilled water with analytical grade CuSO4. 5H2O and CdCl2. 2H2O, which was later diluted as required. The plants were maintained in the water supplemented with 0.35, 0.70 and 1.05 mg/L of Cu for Cu experiment and 0.27, 0.54 and 0.81 mg/L of Cd for Cd experiment. These concentrations for the two elements were chosen arbitrarily. Initially, the healthy plants were kept with different doses of these two chemicals. At the higher doses, the plants died while very low doses got precipitated. At these concentrations, the plants were also healthy. We added chemicals to the water for the desired doses of 0.30, 0.60, and 1.00 mg/L for both the chemicals. However, after addition to the water, the measured quantity was treated as the treatment doses. Plants that were not exposed to metals served as controls. All experiments were performed in triplicates. The test durations were 24 hours, 5 days, 15 days and 25 days. All the buckets were exposed to enough sunlight. Everyday water was added to maintain same level of water in each bucket, to compensate the water loss through plant transpiration, sampling and evaporation. At the end of 25th day, plants were harvested. They were separated into roots, stems and leaves and were analyzed for metal accumulation. In addition, the metals remained in the solution were measured to assess the removal potential of water hyacinth.

Experimental Procedure

30 ml of water sample was collected from each of the buckets after 24 hours, 5 days, 15 days and 25 days of copper treatment. Then all the water samples were filtered with what man filter paper no.1. After 25 days, different parts of plants like roots, stems and leaves were cut and sun dried. The dry weights of these plant parts were taken. Then these plant parts were subjected to acid digestion with 20 ml of 70% HNO3; followed by being kept on hot oven for complete dissolution of the plant parts in the acid given. Further these solutions were filtered using what man filter paper no.42 and filtrate volume was made 25 ml by adding required amount of distilled water. Then the water samples and solution of plant parts were subjected to analysis of metal uptake.

Sample Analysis

Relative Growth: Relative growth of control and treated plants was calculated as follows: Relative growth =Final Fresh Weight (FFW)/ Initial Fresh Weight (IFW)

Metal Accumulation

Metal remained in the residual solution and metal accumulated in the plant sample was measured. Heavy metal analyses were performed on an Atomic Absorption Spectrophotometer using acetylene gas as fuel and air as an oxidizer. Operational conditions were adjusted to yield optimal determination. The calibration curves were prepared separately for both the metals by running suitable concentration of the standard solutions. Digested samples were aspirated into the fuel rich air-acetylene flame and the concentrations of the metals were determined from the calibration curves. Average value of 3 replicated solutions was taken for each determination.

Bioconcentration Factor (BCF)

The BCF provides an index of the ability of the plant to accumulate the metal with respect to metal concentration in the substrate. The BCF was calculated (Zayed *et al,* 1998) as follows: BCF= Concentration of metal in plant issue/Initial concentration of metal in external solution.

Statistical Analysis

The experiments were conducted in three replicates (n=3) for each parameter. The data was subjected to testing the significance of variation among each parameter through analysis of variance. (ANOVA)

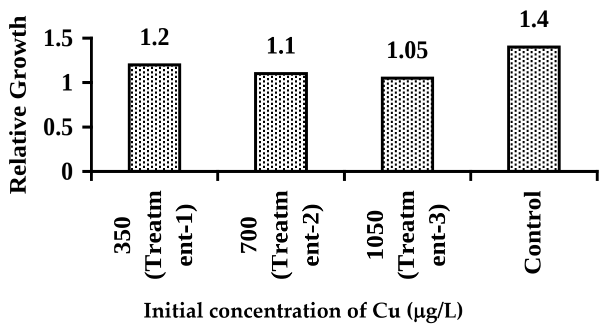

FIG. 1 RELATIVE GROWTH OF THE PLANT *E.crassipes* AT DIFFERENT CONCENTRATIONS OF COPPER

Results

Relative Growth

The effects of Cu and Cd on relative growth of *Eichhornia crassipes* at different concentrations on 25th day are shown in figure 1 and 2, respectively. The relative growth of control plants significantly increased ($p<0.05$). In plants treated with Cu and Cd, the relative growth significantly increased for both the metals in all the treatments.

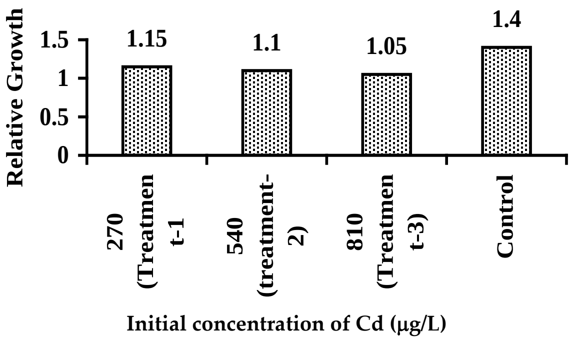

FIG. 2 RELATIVE GROWTH OF THE PLANT *E.crassipes* AT DIFFERENT CONCENTRATIONS OF CADMIUM

Metals Remained in the Residual Solution

The concentration of dissolved Cu and Cd remained in the residual solution are depicted in table 1 and 4, respectively. They were significantly decreased when the exposure times were increased. On 25th day, the concentrations of dissolved Cu in the solutions at 0.35, 0.70 and 1.05 mg/L were found to be 0, 0.5 and 0.11 mg/l respectively. The concentrations of dissolved Cd in the solutions at 0.21, 0.54 and0.81 mg/L were below detectable level on day 25.

TABLE 1 COPPER UPTAKE BY WATER HYACINTH AT DIFFERENT CONCENTRATIONS AND DURATION. VALUES FOLLOWED BY THE SAME SUPERSCRIPTS IN A COLUMN ARE NOT SIGNIFICANTLY DIFFERENT

Initial Concentration of Cu (mg/L)	Residual Concentration (mg/L) of copper			
	24 hrs	5 days	15 days	25 days
0.35	0.10±0.02[a]	0.02±0.01[a]	0.01±0.01[a]	Trace[a]
0.70	0.31±0.02[b]	0.12±0.02[b]	0.08±0.06[b]	0.05±0.01[b]
1.05	0.48±0.05[c]	0.18±0.04[b]	0.17±0.04[b]	0.11±0.02[b]

TABLE 2 COPPER REMOVAL (%) BY WATER HYACINTH AT DIFFERENT CONCENTRATION AND DURATION

Initial Concentration of Cu (mg/L)	Removal (%)			
	24 hrs	5 days	15 days	25 days
0.35	71.42±6.17	93.32±2.69	98.09±7.26	95.23±2.69
0.70	56.18±2.93	82.85±3.08	92.37±1.34	87.61±3.56
1.05	53.95±5	83.17±4.24	89.52±2.33	83.80±2.69

TABLE 3 ACCUMULATION OF COPPER (mg/kg DW) IN ROOT, STEM AND LEAF OF *E. crassipes* AT DIFFERENT CONCENTRATION AFTER 25 DAYS. VALUES FOLLOWED BY THE SAME SUPERSCRIPTS IN A COLUMN ARE NOT SIGNIFICANTLY DIFFERENT

Initial concentration of Cu (mg/L)	Concentration of Cu		
	Root	Stem	Leaf
Control without Cu	0.014[a]	0.181[a]	0.005[a]
0.35	27.8[b]	392.6[b]	10.00[b]
0.70	98.4[c]	1851.00[c]	66.5[c]
1.05	464.9[d]	2314.2[d]	284.8[d]

TABLE 4 UPTAKE OF CADMIUM BY WATER HYACINTH AT DIFFERENT CONCENTRATION AND DURATION. VALUES FOLLOWED BY THE SAME SUPERSCRIPTS IN A COLUMN ARE NOT SIGNIFICANTLY DIFFERENT

Initial Concentration of Cu (mg/L)	Residual Concentration of cadmium (mg/L)			
	24 hrs	5 days	15 days	25 days
0.27	0.08±0.01[a]	0.01±0.0005[a]	Trace	Trace
0.54	0.20±0.05[b]	0.11±0.037[b]	Trace	Trace
0.81	0.56±0.03[c]	0.34±0.10[c]	0.04±0.01	0.01±0.007

TABLE 5 REMOVAL OF CADMIUM BY WATER HYACINTH AT DIFFERENT CONCENTRATIONS AND DURATION

Initial Concentration of Cu (mg/L)	Removal (%)			
	24 hrs	5 days	15 days	25 days
0.27	69.13±6.3	97.52±1.7	100	100
0.54	62.34±9.2	79.62±6.9	100	100
0.81	31.27±4.07	61.72±12	94.23±2.1	98.76±1

Removal of Copper

Removal of Cu by water hyacinth at different concentration and duration is presented in table 2 and that of cadmium in table 5. Results showed high removal (>90%) of copper and cadmium during 25 days experiment. The highest removal was observed on 15th day of experiment, thereafter it decreased for copper while it was almost same after 15 days for cadmium.

TABLE 6 ACCUMULATION OF CADMIUM (mg/kg DW) IN ROOT, STEM AND LEAF OF *E.crassipes* AT DIFFERENT CONCENTRATION AFTER 25 DAYS. VALUES FOLLOWED BY THE SAME SUPERSCRIPTS IN A COLUMN ARE NOT SIGNIFICANTLY DIFFERENT

Initial concentration of Cd (mg/L)	Concentration of Cd		
	Root	Stem	Leaf
Control without Cd	0.214[a]	0.008[a]	0.067[a]
0.27	132.10[b]	4.97[b]	39.18[b]
0.54	189.8[c]	4.98[b]	33.64[b]
0.81	230.39[d]	12.54[c]	19.16[c]

Metals Accumulation

Cu and Cd accumulations by water hyacinth at different concentrations and exposure times are shown in table 3 and 6, respectively. In general, there were increases in Cu accumulation in stems, roots and leaves when copper concentrations were increased. However Cd accumulation in roots and stems was increased and the same in leaves was decreased when Cd concentrations were increased. For Cu, control and plants treated with 0.35, 0.70 and 1.05 mg/l showed a significant difference ($p<0.05$) in metal accumulation. For Cd, significant differences ($p<0.05$) between control and treated plants were found at all metal concentrations. For Cu, the metal accumulation in the stem was the highest but for Cd, maximum metal accumulation was in root. For Cu, metal accumulation was in the order of stem> root> leaf but for Cd, it was root > leaf > stem. It was found that when dissolved Cu concentration was 1.05 mg/L, a metal accumulated in stem was 2314.2 mg/kg dry weight (DW). For Cd, when dissolved Cd concentration was 0.8 mg/L, the metal accumulated in root was 230.39 mg/kg DW.

Bioconcentration Factor (BCF)

The BCF values for Cu and Cd in water hyacinth at different concentrations at 25 days exposure are shown in figure 3 and 4, respectively. The BCF values for Cu significantly increased ($p<0.05$) with the increase in Cu concentration in the experimental water (feed solution). The BCF values for Cd significantly decreased ($p<0.05$) when Cd concentration in feed solutions was increased on 25 days exposure. On day 25, the BCFs of Cu at 0.35, 0.70 and 105 mg/L were 1230, 2990 and 2918 respectively (Fig.3) while those of Cd at 0.27, 0.54 and 0.91mg/L were 653, 423 and 324 respectively (Fig.4).

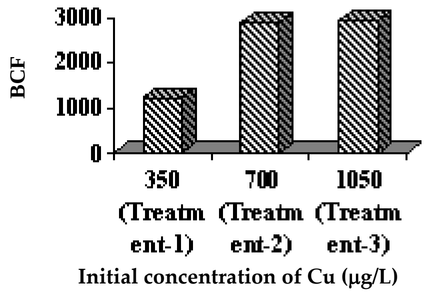

FIG. 3 BCF AT DIFFERENT CONCENTRATIONS OF COPPER

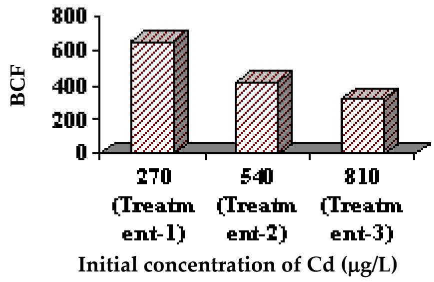

FIG. 4 BCF AT DIFFERENT CONCENTRATIONS OF CADMIUM

Discussion

In the present study, the relative growth increased in plants treated with low concentration of Cd (0.27, 0.54 and0.81 mg/L). It is evident that low Cd concentration could stimulate plant growth. Xiaomei *et al* (2004) reported that relative growth of water hyacinth increased with low concentration of Cd (0.5 and 1.0 mg/L), but decreased with high concentration (2.0 and 4.0 mg/L). Although Cd is not generally considered as an essential element, yet it may stimulate growth of some plants in small amounts (Dou, 1988). In plants treated with Cu, the relative growth increased in all the treatments (0.35, 0.70 and 1.05 mg/L). The addition of Cu at low concentration had a favourable effect on the growth of water hyacinth, which may be attributed to the fact that the plants utilize Cu as a micronutrient for their growth. The Cu removal from the water was more in 15 days than that in 25 days and this could be due to the precipitation of some copper as hydroxides with time.

In the present study, water hyacinth accumulated the highest concentration of metals in stem (For Cu) and in root (For Cd). The accumulation of metals in the roots and shoots of water hyacinth has been shown in field studies in which water hyacinth was used as a biological monitor in metal pollution (Zaranyika *et al*., 1995). Greger (1999) reported that the uptake of Cd, both by roots and stems increased with increasing metal concentration in the external medium but the uptake was not linear in correlation with the concentration increase. The metals accumulations in water hyacinth increased linearly with the solution concentration in the order of leaves<stems<roots in water hyacinth (Stratford *et al*, (1984)). But the present study showed that Cu accumulation is in the order of leaves<roots <stem and Cd accumulation is in the order of stems <leaves< roots. According to the investigation done by Mishra *et al* (2008). translocation factor (i.e. ratio of shoot to root metal concentration) revealed that metals were largely retained in the roots of aquatic macrophytes. Analytical results showed that plant roots have accumulated heavy metals approximately 10 times of its initial concentration.

In general, most studies reported the higher concentration of metals in roots than that in shoots. Cd concentrations were reported to be higher in the roots in most of the studies (Cataldo *et al*, 1981; Rauser, 1987). Normally, Zn, Cd or Ni concentrations are 10 (or more) times higher in root than those in shoot (Chaney *et al*., 1997). Soltan and Rashed (2003) treated water hyacinth with several heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn) and concluded that water hyacinth accumulated higher concentrations of heavy metals in the roots than that in the aerial parts. The present study also demonstrated that cadmium was accumulated more in roots than stem and leaves, though copper was accumulated more in stem than roots and leaves, which could be due to the transmission of Cu from roots to stem with time.

Mishra *et al.* (2008) studied about the effectiveness of three aquatic macrophytes water lettuce, duckweed and water hyacinth for the removal of 5 heavy metals

(Fe, Zn, Cu, Co and Cd) and they found that water hyacinth was the most efficient for the removal of selected heavy metals.

Two processes, root pressure and leaf transpiration primarily control the movement of metal containing sap from the root to the shoot, termed as translocation (Lasat, 2000). Some metals are accumulated in roots, probably due to some physiological barriers against metal transport to the aerial parts, while the others are easily transported in plants. In the present study, the Cu and Cd translocation to the plant aerial parts occurred and continued to go on during the whole experiment. Translocation of trace elements from roots to shoots could be a limiting factor for the bioconcentration of elements in shoots (Zhu *et al.* 1999). It can be proposed that there has mechanism in roots that could detoxify heavy metals or transfer them to aerial parts (Xiaomei *et al,* 2004). Water hyacinth effectively removes appreciable quantity of heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn) from fresh water especially at low concentrations (Soltan *et al,* 2003). Maine *et al,* (2001) reported that remaining Cd concentration in water was inversely related with time and depended on the initial Cd concentration. In the present study, Cu and Cd were efficiently depleted during the first five days of the experiment. The sharp decrease in Cu and Cd concentration remaining in the residual solutions was indicative of the fast attainment of a saturation state. As soon as the saturation state was reached, it seemed a little difficult for plants to further absorb Cu and Cd, till the concentration decreased with the passage of time.

Bioconcentration factor (BCF) is a useful parameter to assess the potential of plants for accumulating trace metals and this value was calculated on a DW. In the present study, the BCF values of *Eichhornia crassipes* in each treatment of copper were significantly higher than those in each treatment of cadmium, indicating that the uptake of copper was better than that of Cadmium. There was a gradual decrease in the Cd uptake potential with an increase in Cd concentration in experimental (feed) solutions. For plants treated with Cu, the BCF values increased with the increase of Cu concentration, indicating that the plant could be more capable of removing Cu from the external concentration. The ambient metal concentration in water is the major factor influencing the metal uptake efficiency (Cain *et al*, 1980; Rai and Chandra, 1992). In general, when the metal concentration in water increases, the amount of metal accumulation in plants increases; whereas the BCF value decreases (Wang and Lewis, 1997). Zhu *et al,* (1999) found that the BCFs of water hyacinth were very high for Cd, Cu, Cr and Se at low external concentration, and they decreased as the external concentration increased. The maximum BCF values for Cd and Cu were 653 and 2918 respectively, indicating that *E. Crassipes* is a moderate accumulator of Cd and hyper accumulator of Cu based on the arbitrary criteria by zayed *et al,* (1998) and Zhu *et al.* (1999). Xiaomei *et al,* (2004) found moderate BCF values for Cd (622.3) and Zn (788.9) in water hyacinth. Zhu *et al,* (1999) found the BCF values of Cd was 2150 for water hyacinth. From the view of phytoremediation, a good accumulator should have the ability to concentrate the elements in its tissue, for example, a BCF of more than 1000 (100 fold compared on a fresh weight basis) (Zayed *et al.* 1998). Based on this criterion, the present study showed that *Eichhornia Crassipes* is a very good accumulator of Cu and a moderate accumulator of Cd with BCF values of 2918 and 653 respectively.

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Bibliography

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A Comparative Study of State-of-the-Art Evolutionary Multi-objective Algorithms for Optimal Crop-mix planning

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Abstract

This study compared the performances of three state-of-the-art evolutionary multi-objective optimization algorithms: the Non-Dominated Sorted Genetic Algorithm II (NSGA-II), the Epsilon-Dominance Non-Dominated Sorted Genetic Algorithm II (ε -NSGA-II) and the Epsilon-Dominance Multi-Objective Evolutionary Algorithm (ε MOEA), on a constrained bi-objective crop-mix planning problem (BCP). The BCP test case objectives were to: (i) maximize crop production and (ii) minimize planting area. The BCP problem was enumerated to provide the true Pareto-optimal solution set to facilitate rigorous testing of the evolutionary multi-objective optimization algorithms. The performances of the three algorithms were assessed and compared using three performance metrics (additive epsilon indicator, inverted generational distance and spacing). For the comparative study, a graphical comparison with respect to true Pareto front of optimal crop planning problem was provided. Results of the analyses indicated that the ε MOEA greatly outperforms the NSGAII and the ε -NSGA-II.

Keywords

Algorithm; Crop; Planning; Constrained; Objective; Optimal; Optimization

Introduction

The increasing growth of human population worldwide calls for sustainable growth of agricultural products to meet the primary need of the population (Lewandowski, Härdtlein, and Kaltschmitt, 1999). The amount of crop produced by agricultural farm will influence profit earned on farm and market prices. If a farm produces a crop in plenty, the market price of crop lowers which favours consumers. Conversely, if they produce in a small amount, the market price may move up and consumers are stuck as they need buy at more expensive price. The constant increase in human population and their activities have intensified pressure on land use for farming. Consequently, the effective planning of crop production in a particular season is an extremely important task from economic perspective.

The crop planning problem is similar to the financial portfolio, that is, a farmer uses his limited land effectively by growing various crops as an investor distributes his funds to some financial stock for "low risk, high returns". Of course, the farm needs the profit information of the crop. This profit information depends upon yield rate, market prices and many other factors. Allocation of the right area of land for the appropriate crop is a task and we may define the planting area as discrete random variable in crop planning. This approach is an alternative, but it is not realistic in any agricultural planning situation to define the allocation of planting area as continuous random variable, because it is difficult. In an agricultural planning situation, optimal production of crops highly depends on the proper allocation of land in different season for cultivating the crops and adequate supply of productive resources to the planning unit.

Many practical problems such as travelling salesman, time tabling and portfolio selection are frequently solved using optimization techniques. Most of these problems involve instantaneous optimization of several incommensurable and often conflicting decision objectives. Although these problems are eminent in engineering and financial sectors, there have related optimization problems in agricultural systems such as crop planning (Adeyemo, Bux, and Otieno, 2010; Chetty and Adewumi, 2013; Sarker and Ray, 2009), irrigation planning (Adeyemo and Otieno, 2010; Bai and Liang, 2012; Sethi, Kumar, Panda, and Mal, 2002) and crop selection (Brunelli and von Lücken, 2009). Each of the multi-objective evolutionary algorithm selected has been demonstrated to be highly effective at solving numerous multi-objective test problems and applications (Zhang *et al*., 2008). As seen in these papers, agricultural problems were formulated as mathematical programming models and solved using a variation of optimization techniques. In particular, linear programming optimization is widely considered for optimal crop planning (Sethi, Kumar, Panda, and Mal, 2002).

The variety of optimization techniques previously considered for crop planning ranges from single to multi-objective and from linear to non-linear forms, where computational intelligence techniques have been explored (Sarker and Quaddus, 2002). However, multi-objective optimization problems are frequently converted into single objective function optimization by predefining weighting functions for different objective functions. The weighting functions express relative importance of each objective function.

The current work explores evolutionary algorithms for constrained multi-objective optimal crop planning decision. There are numerous favourable reasons for using evolutionary algorithms to solve optimization problems. One of the major advantages of evolutionary algorithms when compared to other optimization techniques is that they need little problem specific knowledge and can be applied to a broad range of problems (Zhou *et al*., 2011). Deb *et al.* (Deb, Pratap, Agarwal, and Meyarivan, 2002) identified three primary goals in multi-objective optimization using evolutionary algorithms: (1) to obtain good convergence toward the Pareto-optimal solution set, (2) to develop a diverse, or evenly distributed set of non-dominated solutions and to maintain this diversity throughout the entire run of the algorithm, and (3) to achieve the first two goals at the lowest computational cost and in the most efficient manner possible. This paper is succinctly summarized as follows. In Section 2, we discuss the bi-objective crop-mix planning (BCP) Model. In Section 3, the methodology used in this study is briefly described. In Section 4 we present results of the experiment performed to discover the suitability of NSGAII, ε-NSGA-II and ε MOEA for constrained multi-objective crop planning problem. In Section 5 conclusion is given.

Materials and Methods

The Bi-Objective Crop-mix Planning (BCP) Model

The new mathematical formulation of the annual crop planning considered in this paper is presented. The model is designed to maximize the total crop production that can be produced by minimizing the total planting area. The functions objective is to make full use of the limited resources available in determining the hectare allocation, amongst the various competing crops required to be grown within the year. Assume that a country cultivates a wide variation of crops in different seasons, for instance in summer (October to February), in winter (May to July) and has different land types such as single or double land type. The yield rate, the cost of production and the contribution are functions of soil characteristics (fertility and other soil factors), region, crop being produced, cropping pattern and method (crops being produced and their sequence, irrigation, non-irrigation).

For a single-cropped land, there are a number of alternative crops from which the crop is to be cultivated in a year can be chosen. Similarly, there are many different combinations of crops for double-cropped (two crops in a year) and triple-cropped (three crops in a year) lands. Different combinations give different crop pattern outputs. Land utilization for appropriate crops is an important issue for crop planning decision task. This model can be designed either as a farm level or a wide crop planning. The model is implemented for a wide planning incorporated with the data collected from South African grain information service and South African abstract of agricultural statistics (Statistics, 2012).

Indices

The indices of the model are: i is a crop that can be considered for production, j is a crop combination made up from i and k is the land type.

Input Parameters

The input parameters to the model are: $V_{i,j,k}$ is variable cost required of per unit area for crop i of crop combination j in land type k, $F_{i,j,k}$ is fixed cost required of per unit area for crop i of crop combination j in land type k, $R_{i,j,k}$ is planting area ratio for crop i of crop combination j in land type k, $G_{i,j,k}$ is yield-rate that is the amount of production (metric tons) per hectare of crop i of crop combination j in land type k, W_k is land type coefficient for land type k, L_k is available domain of land type k, D_i is expected delivery (metric tons) of crop i, C_a is working capital (ZAR), which indicates the total amount of money that can be invested for cropping, m is number of alternative crops for single-cropped land, n is number of crop combinations for double-cropped land, q is number of crop combinations for triple-cropped land, M_j is a crop in each j for single–cropped land, j = 1,…,m, N_j is the jth crop pair of the possible crop combinations of double-cropped land, j = 1,…,n and Q_j is the jth crop triple of the possible crop combinations of triple-cropped land, j = 1,…,q.

Variables

The decision variable to the model is $X_{i,j,k}$ the area (hectare) of land to be cultivated for crop i of crop combination j in land type k.

Objective Function 1

Given the choice in terms of profit maximization and constraints that the farm faces in the production process, the farm attempts to produce a specific level of output which requires maximizing crop production. The crop production maximization is described mathematically as follows:

Maximize

$$F_1 = \sum_j^m \sum_{i \in M_j} G_{i,j,k=1} \times X_{i,j,k=1} + \sum_j^n \sum_{i \in N_j} G_{i,j,k=2} \times X_{i,j,k=2} + \sum_j^q \sum_{i \in Q_j} G_{i,j,k=3} \times X_{i,j,k=3} \quad (1)$$

Objective Function 2

From the socio-economic perspective, besides meeting food demand in the society, the attention for cultivation of profitable crops is dependent on proper allocation of land for cultivating the crop. Crop production maximization will therefore require minimizing the planting area as follows:

Minimize

$$F_2 = \sum_j^m \sum_{i \in M_j} X_{i,j,k=1} + \sum_j^n \sum_{i \in N_j} X_{i,j,k=2} + \sum_j^q \sum_{i \in Q_j} X_{i,j,k=3} \quad (2)$$

Constraints

The objective functions considered are to be solved subject to four essential constraints described as follows:

Food delivery constraint: This constraint represents that sum of local production and the production quantity of crop i in a single-crop year must be greater than or equal to the total requirements in the country.

$$\sum_j^m \sum_{i \in M_j} G_{i,j,k=1} \times X_{i,j,k=1} + \sum_j^n \sum_{i \in N_j} G_{i,j,k=2} \times X_{i,j,k=2} + \sum_j^q \sum_{i \in Q_j} G_{i,j,k=3} \times X_{i,j,k=3} \ \geq \ D_i \quad \forall i \quad (3)$$

Land constraint: The sum of lands used for a given type of land must be less than or equal to the total available land of that type.

$$\sum \ \leq L_k \ \ \forall k \quad (4)$$

Where W_1 = 1, for single-cropped land, because no area is shared with other crops W_2 = 1/2, because the same land is used by two consecutive crops in a year on double-cropped land and W_3 = 1/3, because the same land is used by three consecutive crops in a year on triple-cropped land.

Capital constraint: The total amount of money that can be spent for crop production must be less than or equal to the working capital/budget.

$$\sum_j^m \sum_{i \in M_j} (V_{i,j,k=1} \times R_{i,j,k=1} + F_{i,j,k=1}) \times X_{i,j,k=1} + \sum_j^m \sum_{i \in M_j} (V_{i,j,k=2} \times R_{i,j,k=2} + F_{i,j,k=2}) \times X_{i,j,k=2} + \sum_j^m \sum_{i \in M_j} (V_{i,j,k=3} \times R_{i,j,k=3} + F_{i,j,k=3}) \times X_{i,j,k=3} \leq C_a \quad (5)$$

Non-negativity constraint: The decision variables must be greater than or equal to zero

$$X_{i,j,k} \geq 0 \quad \forall \ i,j,k \quad (6)$$

Multi-objective Optimization Algorithms Comparison

In this study, the performances of the NSGAII (Coello, 1999; Deb, Pratap, Agarwal, and Meyarivan, 2002), the ε-NSGA-II (Kollat and Reed, 2005) and the ε MOEA (Deb, Mohan, and Mishra, 2005) are compared using the true Pareto optimal solution set of the bi-objective crop-mix planning problem. All of the algorithms share similarities in that they use real parameter simulated binary crossover (SBX), polynomial mutation, and elitism. Key differences between the algorithms are highlighted in the following sections. It should be noted that this paper assumes a basic prior knowledge of multi-Objective evolutionary algorithms. Readers interested in introductions to multi-objective optimization and evolutionary multi-objective optimization tools should refer to the texts by Deb (Deb, Pratap, Agarwal, and Meyarivan, 2002) and Coello (Coello, 1999).

NSGA-II

The NSGAII is a second generation MOEA developed by Deb *et al*. (Deb, Pratap, Agarwal, and Meyarivan, 2002) which has made significant improvements on the original NSGA by (i) using a more efficient non-domination sorting scheme, (ii) eliminating the sharing parameter, and (iii) adding an implicitly elitist selection method that greatly aids in capturing Pareto surfaces. In addition, the NSGAII can handle both real and binary representations. The NSGAII was chosen for comparison in this study because it has been successfully employed in prior crop planning studies (Sarker and Ray, 2009). For the crop planning problem, all of the algorithms evaluate potential solutions in terms of a vector of objectives.

The concept of Pareto-dominance is used to assign fitness values to the sampling solutions. For example, a solution x_1 dominates another solution x_2 if and only if it performs as well as x_2 in all objectives and better in at least one objective. The fast non-domination sorting approach of the NSGAII ranks each solution according to the number of solutions that dominate it. Once fitness is assigned, two-step crowded binary tournament selection is performed. In cases where two solutions have different ranks, the individual with the lower rank is preferred. Alternatively, if both solutions possess the same rank, then the solution with the larger crowding distance is preferred. Solutions with higher crowding distances add more diversity to the solution population, which helps to ensure that the NSGAII will find solutions along the full extent of the Pareto surface. Refer to Deb *et al*. (Deb, Mohan, and Mishra, 2005) for additional details.

ε -NSGA-II

The *ε* -NSGA-II is based on the NSGAII, which uses a fast non-dominated sorting approach to classify solutions according to level of non-domination and a crowding distance operator to preserve solution diversity (Kollat and Reed, 2005). The *ε* -NSGA-II extends these concepts by adding ε-dominance, adaptive population sizing, and self-termination to minimize the need for parameter calibration as demonstrated by Reed *et al.* (Reed, Minsker, and Goldberg, 2003). *ε* -dominance is a concept whereby the user is able to specify the precision with which they want to obtain the Pareto-optimal solutions to a multi-objective problem, in essence giving them the ability to assign a relative importance to each objective. This is accomplished by applying a grid to the search space of the problem. Larger ε values result in a courser grid while smaller ε values produce a finer grid. The fitness of each solution is then mapped to a box fitness based on the specified ε values. Refer to Laumanns *et al*. (Laumanns, Thiele, Deb, and Zitzler, 2002) for a more detailed description of ε-dominance.

The *ε* -NSGA-II uses a series of "connected runs" where small populations are exploited to pre-condition search with successively doubled population sizes. Pre-conditioning occurs by injecting current solutions within the epsilon-dominance archive into the initial generations of larger population runs. For example, the initial population (usually five individuals) is evolved until it is no longer making significant progress. When this occurs, the population size is increased, subsets of archived solutions are injected into the next population, and the search continues. Under the current design of the algorithm, two injection scenarios exist. If the archive size is smaller than the populations into which it will be injected, the remaining individuals needed to fill the population are randomly generated. However, if the archive is larger than the subsequent population, then individuals are randomly selected from the archive to fill the population. Refer to Kollat and Reed (Kollat and Reed, 2005) for additional details.

ε MOEA

The *ε* MOEA (Deb, Mohan, and Mishra, 2005) is a generational evolutionary algorithm in which all *N* population members (offspring) are created before comparison with parent solutions. In the context of single-objective evolutionary algorithms, it has been adequately shown that computational speed can be achieved by using a steady-state evolutionary algorithm in which every offspring is compared with the parent population as soon as it is created (Deb and Tiwari, 2005). This way, the parent population gets updated in a steady-state manner, thereby providing better chances of creating good offspring solutions. *ε* MOEA uses two co-evolving populations: an evolutionary algorithm population *P(t)* and an archive population *A(t)* (where tis the iteration counter). The multi-objective evolutionary algorithm begins with an initial population *P(0)*. The archive population *E(0)* is assigned with the non-dominated solutions of *P(0)*. Thereafter, two solutions, one each from *P(t)* and *A(t)* are chosen for mating and an offspring solution is created. Thereafter, the solution can enter each of the two populations with different strategies (Coello, 1999).

Results

In this section, we presented the experiments conducted and discussed the results obtained. To allow a fair comparison among the approaches used, a criterion normally used in evolutionary multi-objective optimization was adopted; all the algorithms were performed for the same number of fitness function evaluations and the combination of parameters chosen for each of the algorithms compared was appropriate for the approach to have a reasonably good performance. This can be corroborated by checking the original sources of each of the methods compared. The NSGA-II, ε -NSGA-II and ε MOEA methods were implemented using NETBEAN version 7.3, on an HP PC with Pentium dual core processor having 2.30 GHz clock speed and 4 GB of RAM.

Parameter Setting

In this study, the NSGAII and the ε MOEA were parameterized according to the most commonly recommended settings from the evolutionary multi-objective optimization literature. It should be noted that all of the tested algorithms used simulated binary crossover, polynomial mutation and elitism. All of the algorithms utilized the same probabilities of crossover and mutation (p_c = 0.9, and $p_m = 1/N$, respectively, where N is the population size), and the same crossover and mutation distribution indices (η_c = 20 and η_m = 20, respectively) associated with each of these operators. The NSGAII and ε MOEA were assigned a population size of 100 individuals based on recommendations in prior literature (Deb, Pratap, Agarwal, and Meyarivan, 2002; Deb, Mohan, and Mishra, 2005). The ε -NSGA-II used adaptive population sizing and automatic termination, thus requiring only a starting population size (for this study, N_i = 10 was chosen) and termination criteria that required at least a 10% improvement in the non-dominated archive. The relevant parameterization of each of the algorithms is summarized in Table 1.

TABLE 1 SUMMARY OF ALGORITHM PARAMETERS USED IN THIS STUDY

	NSGAII	**ε -NSGA-II**	**ε MOEA**
Population size, N	100	Dynamic starting with 10	100
Termination criteria	200,000 Evaluations	<10% Improvement	200,000 Evaluations
Crossover Probability, p_c	0.9	0.9	0.9
Crossover dist. Index, p_m	20	20	20
Mutation Probability, η_c	$1/N$	$1/N$	$1/N$
Mutation dist. Index, η_m	20	20	20
Variable representation	Real	Real	Real

In order to accurately assess the reliability of each algorithm, 50 random seeds were chosen resulting in 50 random seed trial runs for each algorithm. It should be noted that identical random seeds were specified for the NSGAII, ε -NSGA-II, and ε MOEA since they all use the same random number generator. The impacts of random number generator differences were minimized in this study by using 50 trial runs for statistical performance assessment of each multi-objective evolutionary algorithm. In order to facilitate a fair performance comparison, the ε -NSGA-II was run for 50 random seed trial runs and the average number of design evaluations required to automatically terminate was used as a basis for parameterizing the runtime of the NSGAII and ε MOEA, for the same random seeds. Parameterizing the runtime of the other algorithms in this manner gave each algorithm the same opportunity to generate the Pareto front for the crop planning problem. However, it was observed that this maximum runtime for the NSGAII and the ε MOEA would not be known in advance, requiring the user to estimate the runtime needed to sufficiently solve their problem using trial-and-error analysis.

Performance Metrics

To aid in assessing the performance of each algorithm based on these criteria, several performance metrics which assign a measure of quality to the algorithms solutions were used. Performance metrics can be used to assess the quality of the end result, or to visualize the dynamics of the runtime performance of the algorithms. This is particularly useful when comparing multiple algorithms. When the end results of the algorithms do not differ substantially, the way in which they achieve these results throughout their run may provide more information regarding performance. In this study, three performance metrics are used: additive epsilon indicators, generational distance and inverted generational distance (Zitzler, Thiele, Laumanns, Fonseca, and da Fonseca, 2003) to evaluate the average final performances of the algorithms. The performance metrics used in this study require a reference solution set for comparison purposes. The reference set can represent the true Pareto-optimal solution set or the best known approximation to the Pareto-optimal set attained through previous algorithm runs or by other means. In this study, if a metric required a reference set, the true bi-objective Pareto- optimal set for the crop planning problem was used.

The additive epsilon indicator proposed by Zitzler *et al*. (Zitzler, Thiele, Laumanns, Fonseca, and da Fonseca, 2003) makes direct use of Pareto dominance and is highly intuitive. For two approximation sets A and B, epsilon indicator can be thought of as a measure of minimum distance to shift set *B* by so that set *A* only just dominates it. A set of objective vector is called approximation set if any element of the set does not weakly dominate any other objective vector in set (Zitzler, Thiele, Laumanns, Fonseca, and da Fonseca, 2003). The generational distance represents average distance from solutions in an approximation set to the nearest solution in the reference set of the problem. Inverted generational distance indicates how far is the true Pareto-optimal front from the front obtained by each of the algorithm. An algorithm A is better than algorithm B in terms of convergence, if inverted generational distance of algorithm A is less than inverted generational distance of an algorithm. For additional details on the additive epsilon indicator, generational distance and inverted generational distance metrics, see Zitzler *et al*. (Zitzler, Thiele, Laumanns, Fonseca, and da Fonseca, 2003) and Knowles and Corne (Knowles and Corne, 2002).

Performance Results

Figure 1 presents results of additive epsilon indicator, generational distance and inverted generational distance versus total number of function evaluations for each of the algorithms compared. The results of all 50 random seed trial runs are shown in the figure with the mean performance indicated by a solid line and the range of random seed performance indicated by the shaded region. Visualizing the results in this manner allows for comparison between the dynamics and reliability (i.e., larger shaded regions indicate lower random seed reliability) of each algorithm. The first row of plots portraying additive epsilon indicator reveals that ε MOEA exhibits higher reliability compared to NSGA-II and ε -NSGA-II. NSGA-II produces the lowest random seed reliability. Generational distance metric results are shown in the second row of Figure 1.

The generational distance metric displays a similar trend in additive epsilon indicator. The NSGAII performs poorest in terms of generational distance and has a low reliability. The ε -NSGA-II outperforms the NSGAII but achieves a slightly high level of reliability. The ε MOEA attains the best generational distance and maintains this superiority throughout its entire run when compared to the NSGAII and ε -NSGA-II. Inverted generational distance metric results are shown in the third row of Figure 1.

TABLE 2 MEAN AND STANDARD DEVIATIONS OF THE METRIC RESULTS FOR ALGORITHM PERFORMANCE ACROSS 50 RANDOM SEED TRIAL RUNS

	Add. Epsilon Indicator	Generational dist.	Inverted Gen. dist.
	mean (std. dev.)	mean (std. dev.)	mean (std. dev.)
NSGA-II	1.556 (0.4554)	0.566 (0.4422)	0.044 (0.0128)
ε -NSGA-II	1.952 (0.8653)	0.968 (6.1222)	0.087 (0.0536)
ε MOEA	0.144 (0.0505)	0.430 (0.0367)	0.021(0.0004)

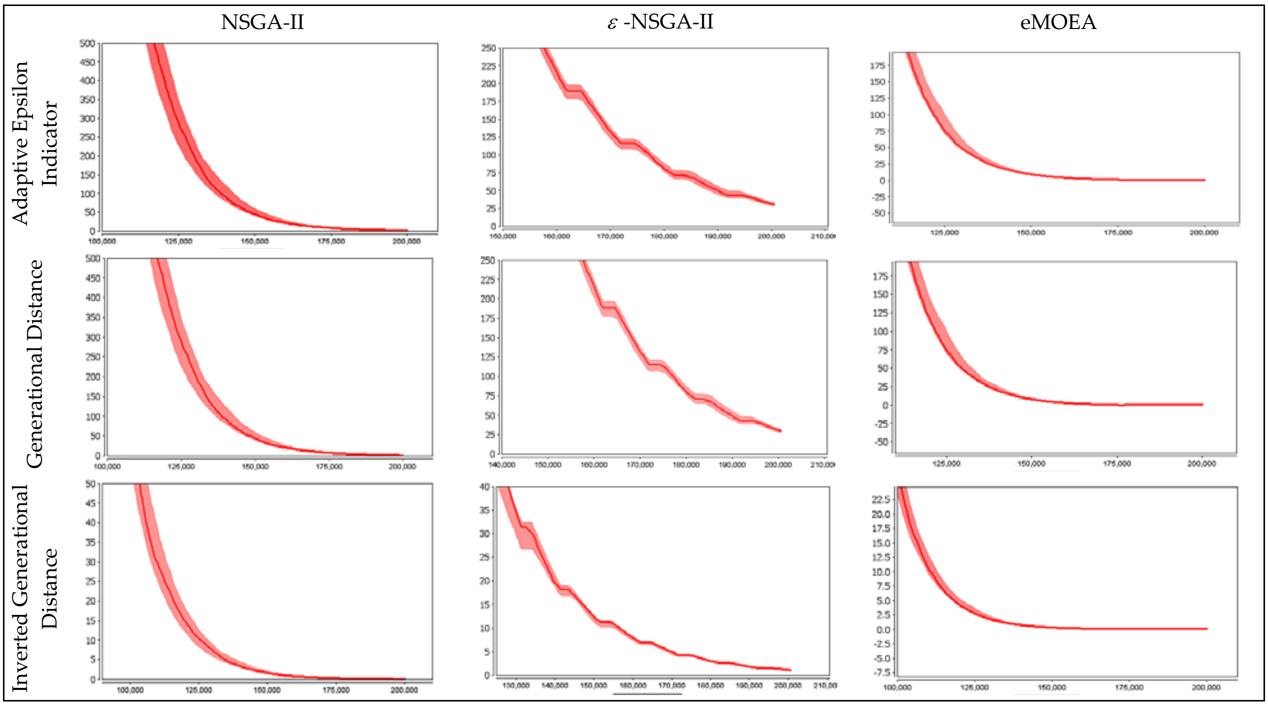

FIG. 1 DYNAMIC PERFORMANCE PLOTS OF: ADDITIVE EPSILON INDICATOR, GENERATIONAL DISTANCE AND INVERTED GENERATIONAL DISTANCE VERSUS TOTAL NUMBER OF FUNCTION EVALUATIONS FOR NSGAII, ε -NSGA-II AND ε MOEA FOR 50 RANDOM SEED TRIAL RUNS. MEAN PERFORMANCE IS INDICATED BY A SOLID LINE, AND THE RANGE OF PERFORMANCE BY THE SHADED REGION

Additive epsilon indicator, generational distance and inverted generational distance metric results are shown in Table 2. The average additive epsilon indicator results reveal that the additive epsilon indicator measure achieved by the ε MOEA is an order of magnitude lower than that achieved by the other algorithms indicating superior performance. The ε -NSGA-II performs poorest in terms of its additive epsilon indicator measure. In addition, the ε MOEA achieves the lowest standard deviation of all algorithms in this measure. Interestingly, the NSGAII performs better in this measure than the ε -NSGA-II indicating that even though the NSGAII finds fewer solutions, the spread of the solutions throughout the objective space dominates a distance greater than that of the ε -NSGA-II.

The generational distance metric represents the smallest distance on average that an algorithm's approximation sets must be translated to completely dominate the true Pareto-optimal set. The results of this metric indicate that the ε MOEA requires the smallest average translation distance and that the ε -NSGA-II requires the largest translation distance on average. In addition, the ε MOEA achieves the smallest standard deviation in this measure compared to the other algorithms.

The results of inverted generational distance metric indicate that the ε MOEA produces the shortest distance between the true Pareto front and front while the ε -NSGA-II produces the longest distance between the true Pareto front and front. In addition, the ε MOEA achieves the smallest standard deviation in this measure compared to the other algorithms.

Since performance metrics can sometimes be misleading in multi-objective optimization, it is always important to rely on graphical comparisons, whenever possible (Zhang *et al.*, 2008). When analyzing the Pareto front produced by an approach, it is important to identify two main things (1) if the solutions are placed on the true Pareto front (which is indicated as a continuous line in this case), and (2) how uniform the distribution of solutions is along the Pareto front.

Figure 2 shows the Pareto optimal front produced by NSGA-II, ε -NSGA-II and ε MOEA for the crop-mix planning model when maximizing total crop production and minimizing total planting area. NSGA-II has produced a lot of points on the top portion of the front, but it had some small holes on the lower portion. The ε -NSGA-II had problems with the distribution of points from the top section of the Pareto front as seen in Figure 2. ε MOEA had a few problems both at the top and bottom portions, but it managed to produce most of the front. ε MOEA had a very good distribution of the solutions.

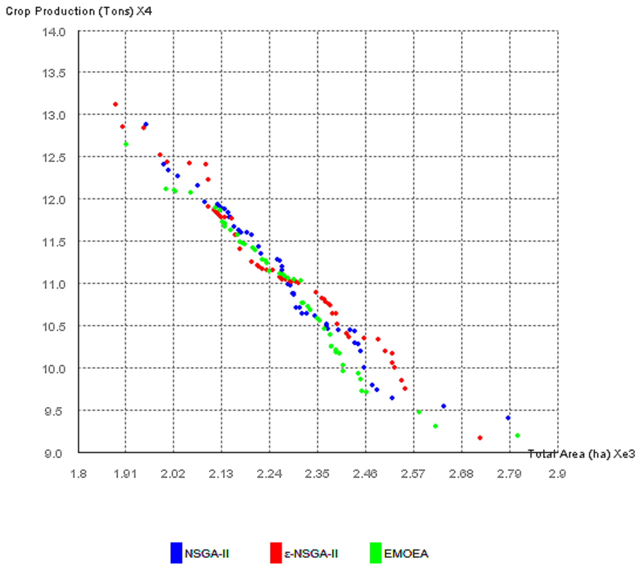

FIG. 2 PARETO OPTIMAL FRONT PRODUCED BY NSGA-II, ε -NSGA-II AND ε MOEA FOR THE CROP-MIX PLANNING MODEL WHEN MAXIMIZING TOTAL CROP PRODUCTION AND MINIMIZING TOTAL PLANTING AREA

Conclusion

This study compared the performance of three state-of-the-art evolutionary multi-objective optimization algorithms (the NSGAII, the ε -NSGA-II and the ε MOEA) on a bi-objective crop-mix planning problem. The crop-mix planning problem objectives were to: (i) maximize crop production and (ii) minimize planting area. The problem was enumerated to provide the true bi-objective Pareto-optimal solution set to facilitate rigorous testing of the evolutionary multi-objective optimization algorithms. The performances of the three algorithms were assessed and compared using three runtime performance metrics (additive epsilon indicator, generational distance and inverted generational distance). The results of this study indicated that the ε MOEA produced improved results when compared to NSGAII and the NSGAII's performance exceeding that of the child algorithm, ε -NSGA-II. Given the features of ε MOEA, an extension of the paradigm for multi-objective optimization can be particularly useful to deal with dynamic functions. As part of future work, other optimization methods can be compared to ε MOEA to establish its superiority over many other methods for crop planning decision making. The performance comparison of these optimization algorithms was valuable for a decision maker to consider tradeoffs in method accuracy versus method complexity. Finally, future work will extend ε MOEA to solve transportation problem in crop planning.

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Impact of Technological Change on Wheat Production Risk in Northwest of Iran

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Abstract:

There have been many previous studies about technical efficiency in wheat production in different areas in Iran, but attention was paid to impact of input utilization on production Risk and none has focused on impact of technological change on production risk. Thus in this study we tried to determine whether technology has a positive or negative effect on production variation. To achieve this aim, a stochastic frontier production function with a heteroske-dastic error structure has been used. A 10-year panel dataset from 8 province (Azarbayjan-e-sharghi, azarbayjan-e-gharbi, Ardebil, Kurdestan, Kermanshah, Lorestan, Zanjan, Eilam) in northwest of Iran was used to estimate different functional specifications. The results indicated that Potash fertilizer and technological change have positive and significant impact on wheat production risk; as well land and labour have a positive effect on wheat production risk but these coefficients are not statically significant. Plus, using phosphate and nitrogen fertilizer and seed have negative and significant impact on wheat production risk.

Keywords

Heteroskedastic Error Structure; Northwest of Iran; Stochastic Frontier Production Function; Technological Change

Introduction

Producing a product is a risky activity and inherent uncertainties which result in variation in production have been indicated in literature especially in agricultural sector (Ogundariand Akinbogun 2010). Farmers face risk from a variety of sources, including price risk, input risk, and production risk, all of which cause uncertainty in profit and thus input choice decisions (Picazo-Tadeo and Wall, 2011). Production risks are dependent on weather, input utilization and other external factors (Läänemets et al, 2011). However, variation in production can be investigated by inputs. This method has been known as a production risk in input (Bokusheva and Hockmann, 2006; Villano and Fleming, 2006). Since technological change can be very risky action especially in developing countries, risk-averse producers will be concerned about risk properties when they consider the adoption of new technologies; so, they may not choose the technology with the highest mean output (Ogundari and Akinbogun 2010).

Wheat is the most important agricultural production in the world and it plays an important role in food security and nourishment in developing countries. The wheat seed storage proteins are a major source of protein in the human diet, and responsible for the properties of wheat dough that allows a wide range of food products (Claudia et al, 2007). Hence, many people in developing countries especially the urban and rural poor are largely dependent on the performance of wheat economy (Ahmad et al, 2002).

In recent years, wheat has occupied a dominant position in agricultural policies of Iran and govern-ments have been trying to achieve self-sufficiency in wheat production, because of this goal, most of production factors have been given to the farmers with subsidy; however, this program has not been successful because it imposed a great cost on government budget. In addition, due to this program, the producers are not able to use agricultural production factors at optimum level. Hence, this policy affects the yield and production volatility negatively (Semerci et al, 2012). Developing technology in wheat production can be a very important and useful measure to reach the self-sufficiency in Iran. However, as mentioned above, in developing country such as Iran, technological change can be a very risky decision for farmers and it may have a disastrous impact on production.

Northwest of Iran is the most important area in a wheat production and more than 70 percent of Iran's wheat production have been produced in these provinces (Azarbayjan-e-sharghi, azarbayjan-e-gharbi, Ardebil, Kurdestan, Kermanshah, Lorestan, Zanjan, Eilam) in 2009 (Iran's agricultural censes, 2009). So, the study of impact of technological change and other production factors on production risk has been investigated.

Because of the importance of production risk, a lot of researches have been done to investigate the impact of production input utilization on production risk (Abedullah and pandey. 2004; Ligeon et al. 2008; Ogada et al. 2010; Lyman and Nalley. 2013).

Wanda (2009) investigated the effect of inputs and banana agronomic management practices on the mean yield and yield variability of bananas in Uganda. Just and Pope stochastic production function specification has been used to analyze the relationship between inputs and banana yield under production risk. The result showed that labour, mulch and manure had a negative effect on variability in banana yields while fertilizer, agronomic frequency and extension increased the variability in yields of bananas across the sample farmers.

Carew et al (2009) used Just-pope production function to examine the relationship among fertilizer inputs, soil quality, biodiversity indicators, cultivars qualified for Plant Breeders' Rights (PBR), and climatic conditions on the mean and variance of spring wheat yields in Monitabo Canada, and the main result showed nitrogen fertilizer, temporal diversity, and PBR wheat cultivars were associated with increased yield variance.

Krishna et al (2009) used a just pope approach to investigate the impact of Bt cotton technology and on-farm varietal diversity on production variation. The result showed that both of these factors enhance yield and reduce the production risk.

Gardebroek et al (2010) compared the production technology and production risk of organic and conventional arable farms in the Netherlands. Just–Pope production functions have been estimated for Dutch organic and conventional farms. The result showed that organic farms face more output variation than conventional farms. Manure and fertilizers are risk-increasing inputs on organic farms and risk-reducing inputs on conventional farms. Labour is risk increasing on both farm types; capital and land are risk-reducing inputs.

Picazo-Tadeo and Wall (2010) in part of their study used a just-pope approach and it was indicated that land, labor, and fitosanitary products are risk-reducing inputs, whereas capital, seeds, and fertilizer all increase risk in rice production in spain.

Also, in Iran some studies have focused on different agricultural production inefficiency and use of inputs on risk production in different area of Iran (Torkamani and Ghorbani, 1997; Mousavi et al, 2007) but none of these studies made the emphasis on impact of technological change on production variation. So, the main purpose of this study was to investigate the impact of technological change and other inputs on production risk in wheat production in northwest of Iran.

Materials and Method

In order to determine the effects of input factors on the level of yield and its variability, the stochastic production function approach pioneered by Just and Pope (1978, 1979) is applied. The fundamental concept underpinning this approach is that the production function can be decomposed into two section: the first part is linked to the mean output level while the second segment is associated with the variability of that output (Cabas et al., 2010; Kim & Pang,2009).

The general form of the Just and Pope production function is (Just and Pope 1978):

$$y = f(X) + g(X)\epsilon, \quad (1)$$

where y is yield and X is a set of explanatory variables. The parameter estimation of $f(X)$ shows the average impact of the explanatory variables on yield and $g(X)$ offers their effect on the variability of yield (Chen & Chang, 2005). According to different studies production function of the following form, it has been estimated:

$$y = (x) + u = f\ (X, \beta) + g(X, \alpha)\epsilon, \quad (2)$$

where y is wheat yield, X is a set of explanatory variables (land, labour, seed, Potash, phosphate and nitrogen fertilizer and time period as an index of technological change) and ϵ is an exogenous production shock with $E(\epsilon) = 0$ and $\mathrm{Var}(\epsilon) = \delta_\epsilon^2$ as it has been shown that the explanatory variables affect both the mean and variability of wheat yield, because $E(y) = f(x)$ *and* $Var(y)=Var(u)=g(.)$. The parameter estimation of $g(.)$ gives the average effects of the explanatory variables on yield, whilst $g(.)$ reveals the impacts of the covariates on the variability of yield. It is noteworthy that a positive sign on any parameter of g(.) implies that a rise in that variable indicates an increase of the variability of yield. On the other hand, negative sign on the same variable indicates decrease of the variability production.

Three functional forms of production functions: Cobb-Douglas, quadratic and translog are used for the Just and Pope Production function (Kim and Pang, 2009). Because of the multiplicative interaction between the mean and variance, a translog functional form would violate the Just and Pope assumption (Sarker et al, 2012) and for liner quadratic provided poor estimate. In addition, cobb-Douglas production function has been the best functional form in different studies (Kebedeand Adenew, 2011; Hassan et al 2010; Khanal et al 2010). Therefore, we selected Cobb-Douglas form for the mean yield function estimation. This functional form is consistent with the Just and Pope assumption (Kim & Pang, 2009).

Mean function:

The mean function is specified as:

$$y = \alpha_0 + \alpha_t T + \prod_i x_i^{\alpha_i} \quad (3)$$

Where x_i is explanatory variables and T represents time trend, which can capture the technological change and α_i implies coefficients to be estimated.

Variance function:

Linear functional (Cobb-Douglas) form has been considered for the variability function because the variance function has a non-linear form. Following Just and Pope (1978 & 1979), the variability function g(.)is modelled in a Cobb-Douglas form as follows:

$$g(x) = \beta_0 T \prod_i x_i^{\beta_i} \quad (4)$$

Where$\beta_i s$ are parameters to be estimated.

Fixed effect and random effect models are usually used for a panel model (Baltagi, 2005). In this study, fixed effect model has been used (McCarl et al., 2008; Barnwal and Kotani, 2010; and Cabas et al., 2010).

Panel unit root test and stationarity of variables:

It is essential to investigate the presence of unit roots for each variable before estimating the model. One important assumption of the Just and Pope model is that the variables under estimation are stationary (Chen et al., 2004). As using a non-stationary data set might yield bias results (Chen and Chang, 2005). However, the time series properties of one variable comprising many regions/areas in a panel data setting are hard to characterize (Chen et al., 2004). This study used the LLC (Levin, Lin, Chu) to investigate the stationary of variables.

Data

In this study, a panel data for 8 province (Azarbayjan-e-sharghi, azarbayjan-e-gharbi, Ardebil, Kurdestan, Kermanshah, Lorestan, Zanjan, Eilam) in northwest of Iran for ten years, since 2000 to 2009, has been used gathered from Iran's agricultural census in these years.

Results and Discussion

Unit root test:

In table 1, results of panel unit root test have been represented. The null hypothesis of LLC test is that panels contain a unit roots and opposite hypothesis express that panel is stationary. As it has been shown that the null hypothesis of unit roots is rejected at the 1% level of significance for all variables in the model. So, all variables under the model are stationary.

TABLE1 RESULT OF STATIONARY TEST

Variable	LLC statistic (adjusted)	P-value
Wheat production	-3.65	0.0001
Land	-2.88	0.002
Labour	-1.32	0.09
Seed	-1.84	0.03
Nitrogen fertilizer	-3.74	0.0001
Phosphate fertilizer	-2.30	0.010
Potash Fertilizer	-1.88	0.029

TABLE 2 ESTIMATION RESULT FOR WHEAT PRODUCTION

Variable	Coefficient	Z-statistic	p-value
Mean Function			
Land	1.077	6.70	0.000
Labour	-0.11	-3.37	0.001
Seed	0.12	0.86	0.39
Nitrogen Fertilizer	0.034	1.11	0.26
Phosphate Fertilizer	0.026	1.15	0.25
Potash Fertilizer	-0.003	-1.94	0.05
Technological change	0.014	4.2	0.00
Constant	-1.56	-4.44	0.00
Variance Function			
Land	4.38	1.27	0.20
Labour	1.45	1.61	0.10
Seed	-5.59	-1.81	0.071
Nitrogen fertilizer	-1.54	-1.23	0.22
Phosphate fertilizer	-1.09	-1.73	0.083
Potash Fertilizer	0.19	2.27	0.023
Technological change	0.26	3.31	0.001
Log likelihood =101.67832	Wald chi2(7)=2463.09	Prob > chi2= 0.0000	

Results for mean and variance function:

The result of Cobb-Douglas production function estimation is represented in table 2. The first part of this table represents coefficients of the mean function and the second part of this table represents coefficients of variance function. Coefficients of mean function represent the elasticities of the included variable inputs. The elasticity of 1.077, -0.117, 0.121, 0.0346, 0.026, -0.0037 and 0.014 are obtained for land, labour, seed, nitrogen fertilizer, Phosphate fertilizer, Potash Fertilizer and technological change. As it has been indicated that land has the greatest positive impact on a wheat production and its coefficient is statically significant. Moreover, technology improvement has a positive and significant impact on wheat production in this area. The elasticities which have been estimated for seed, nitrogen fertilizer and Phosphate fertilizer have a positive effect on wheat production; however, these coefficients are not statically significant. Moreover, the elasticities which have been estimated for labour and Potash Fertilizer have a negative impact on the wheat production.

The coefficient of the production risk in inputs has been represented in table 2, and these coefficients of variance function also represent the elasticities of the included variable inputs for variance function. The elasticities of 4.38, 1.45, -5.59, -1.54, -1.09, 0.19 and 0.26 were obtained for land, labour, seed, nitrogen fertilizer, Phosphate fertilizer, Potash Fertilizer and technological change. These coefficients indicated that land is a risk increasing inputs, however, it is not statically significant. While labour, potash fertilizer and Technological change are risk increasing inputs and these coefficients are statically significant. Hence, the study assumption about the positive impact of technological change on production variability has been accepted. Further, risk-averse farmers in these provinces are expected to use lees labour and potash fertilizer and not willing to adopt a new technology compare with risk-neutral farmers; because these actions can increase the production variability. On the other hand, seed, nitrogen and phosphate fertilizer have negative impact on production variability; among which seed is the greatest. So, risk-averse farmers might use these inputs in order to reduce the production risk and the revenue variability.

Conclusion

The main purpose of this study was to investigate the impact of technological change and other inputs on production risk in wheat production in northwest of Iran. To achieve this aim, a stochastic frontier production function with a heteroskedastic error structure has been used.

According to production function and variance function estimation, the study concluded that a better insurance policy should be adopted, which can provide a safer condition for wheat producer in these province, leading to optimum utilization of input; as some of these inputs, like seed, are overused in order to reduce the production risk.

Also, as it has been represented above, technological change and improvement have a positive effect on wheat production and production risk; so, if Iran's agricultural insurance fund designs a insurance package to cover the Potential damage arising from changes in technology, it might cause a safer condition for wheat producers, and leading to increased production of this strategic production by using new technology.

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Rheological Measurements for Indicating Structural Changes in selected Soil Catenas of European Experimental Fields

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Abstract

Characterization of soil degradation and changes of soil quality are of great importance. The effects of the mismanagement in Puch experimental station (Germany), the differences between bio and conventional agriculture in the plots of Basilicata and Tuscany (Italy) and the effect of vegetation cover in Santomera field (Spain) were studied by rheological measurements. The rheological parameters were measured in suspensions containing as much water as equilibrium sediment can be retained during long standstill, introduced by Czibulya et al. (2010) as the water content of soil suspension in corresponding state (*WCSSinCS*). Rheological parameters were determined under soil relevant conditions (low shear, high viscosity), where surface properties of soil particles and composition of aqueous phase governed rheological behavior of suspensions, and were compared with parameters related to the organic matter content of soils such as total organic carbon (*TOC*), soil organic matter content (*OM*) and humic substances carbon (*Chum*) values measured within a European specific targeted research project (acronym: INDEX-GOCE-CT-2003-505450) and it was explored that the flow ability of soil suspensions in corresponding state is influenced by liquefying and solidifying effects. The higher WCSSinCS indicates better water holding capacity of soils liquefies suspensions, since the number of particles in the unit volume of suspensions decreases. The increase of organic matter content can induce higher shear resistant aggregation structure only if adequate Ca^{2+}-ion is available. The ratio of organic matter content to that of Ca^{2+}-ion is also high, but its liquefying effect comes out for lack of Ca^{2+} ions.

Keywords

Rheology; Soil Suspensions; Soil Degradation; Remediation

Introduction

As Markgraf et al. (2006) introduced rheometry as a suitable method to determine the mechanical behaviour of soils and mineral suspensions when subjected to external stresses, investigations were made on several soil suspensions to characterize them, and to follow the structural degradation (Szegi et al, 2006). Although some articles on soil rheology (Barnes, 1997; Bongiovanni and Lobartini, 2006; Bronic and Lal, 2005; Ghezzehei and Or, 2001; Ghezzehei and Or, 2003; Lipiec and Hatano, 2003; Or and Ghezzehei, 2002) have explained the basic principles and contain advanced research involving even viscoelastic models for soil suspensions dealing with the thixotropy of the soil suspensions; the significant influence of solid/liquid ratio is rarely in consideration (Czibulya et al., 2010, Holthusen at al. 2012).

The rheological parameters of soils can not be measured directly; and soil suspensions have to be prepared for these measurements. As stated in one of our previous work (Czibulya et al., 2010), an acceptable protocol involving the appropriate particle size, temperature, water content, time of standstill was determined. Under adequate circumstances of suspension preparation, storage and measuring, the rheological parameters are able to characterize soil quality. This protocol proved to be suitable to test the structure formation ability of the colloidal fraction of soil samples, which plays fundamental role in the formation of micro- and macro-aggregates in soils. Fine structural details related to particle adhesion, sensitivity to mechanical effects, breakdown and recovery of particle network structure can be identified on the basis of rheological measurements (Czibulya et al. 2010), and soil catenas can be characterized. It has been proved that the rheological parameters of soil suspensions, characteristic of the formation and strength of cohesive structure (the absolute yield stress, the initial shear strength, the thixotropic loop area) under soil relevant condition, change parallel and depend significantly on the water content in soil suspensions as expected from the fundamentals of rheology. However, the extrapolated yield values and the plastic viscosity belong to the plastic flow region above the breakdown of cohesive structure, and so these are not suitable for the structural characterization of particle network building up for long period (Czibulya et al., 2010). Indicating soil quality (Karlen et al., 2003) is not simple at all, because soil quality depends on plenty of chemical, physical and biological processes and parameters.

There are different kinds of models which can predict soil loss degradation, soil quality change, but these models need several parameters determining previously (Michael et al., 2005) such as the capacity of a soil to produce biomass (Schoenholtz et all., 2000), dissolved organic matter (*DOM*) and water extractable organic matter (*WEOM*) contents (Zsolnay, 2003; Akagi et al., 2007; 2008), microbiological mass of carbon and enzyme activity, which decreases parallel with decreasing plant cover (Bastida et al., 2006; 2007; Albiach et al., 2000). All of these give partial information about the degree of soil degradation and soil quality.

In order to obtain comparable data for structural characterisation of different soils, a measuring protocol for rheology of soil suspensions in corresponding state has been developed in a European collaborative project (INDEX) and published (Czibulya et al., 2010). Several series from INDEX sample pool have been measured and evaluated according to the structural change either degradation or improvement, respectively. In the present work some noteworthy rheological and equilibrium water content results for the samples of soil catenas will be shown and compared with the other chemical parameters such as the organic matter (*OM*), the total organic carbon (*TOC*) and humic substances carbon (*Chum*) contents measured in the course of INDEX project, which are well-known quantities in soil science and indicate the quality of soils (Brady, 1999; Bastida et al., 2008).

Materials and Methods

Materials

Different catenas in Germany, Italy and Spain were sampled in 2004 and 2005 then analized. The long term experimental fields in Puch and the biological and conventional agriculture in Italy were compared; while the effects of plant cover were investigated in Santomera.

On the long-term (over 50 years) cultivation field in Puch (Germany), three kinds of samples were collected: “Agri/Agriculture” was a sub-field under normal cultivation, winter wheat (*Triticum aestivum L.*) was grown on the agricultural plot at the time of sampling. “Green” was a strongly mismanaged field, without any control or fertilisation, and normal plant development was not allowed to take place by intensive ploughing twice a year. “Black” was a black fallow, in which an extreme case of mismanagement is mimicked without fertilisation and ploughed whenever vegetation appeared. Each plot was about 450 m^2 with a sandy loam, Luvisol (WRB 2006), with the annual precipitation 900 mm y^{-1}, and 8 ^oC mean temperature (Akagi et al., 2007; INDEX Site description). The fractions less than 1 mm were used to prepare suspension, practically 100% of the Puch samples.

Agricultural experiments were continued in Italy: Basilicata and Tuscany, for more than four years. The soil types of the experimental fields were Cambisol, Vertisol (WRB 2006), respectively (Masciandaro, 2008; Bronic and Lal, 2005). Biological agriculture (BA) and conventional cultivation (CA) fields were compared. In conventional tillage besides green manure used in BA, cropping and mineral fertilizer (25% N and 15% P added as ammonium nitrate and ammonium phosphate) were applied. The used fraction (< 1 mm) was above 90% of soil samples in both cases.

The catena of Santomera (Murcia, Spain) is Mediterranean semiarid lowland with *Pinus halepensis* and natural shrubs. The plant coverage of this sampling field changes from the highest (Forest), through medium ~50% (Shrub) to a more degraded soil with only ~25% vegetation coverage (Bare). The devegetated area was subjected to clipping treatments whereby all canopy cover was removed (Deveg Fm). This area was contrasted with the natural or undisturbed area (Forest Fp). The Santomera catena has a sandy loam soil, Calcisol (WRA 2006). The region has an annual precipitation of 300 mm y^{-1} and a mean temperature of 18^oC. The used fraction (< 1 mm) was 50-90% of these soil samples.

Methods

1) Determination of Water Content of Soil Suspensions in Corresponding State

Soil suspensions have to be prepared from the soil samples to measure rheological properties. The water content of equilibrium sediment formed spontaneously from dilute soil suspensions after long standing under gravitational pull was determined in glass tube experiments as shown for Santomera samples in Fig. 1. The equilibrium sediment can be considered as a "corresponding state of soil suspensions", therefore its water content is characteristic of soils (Czibulya et al., 2010).

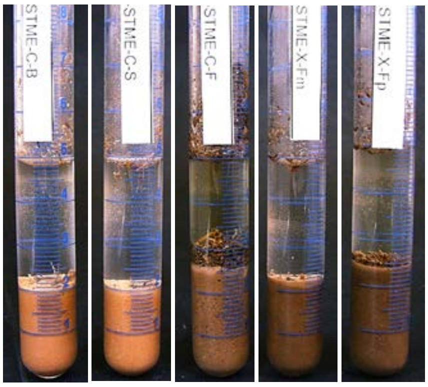

FIG. 1 GLASS TUBES CONTAINING THE EQUILIBRIUM SEDIMENTS OF SOIL SAMPLES FROM SANTOMERA CATENA (B - bare, S - shrub, F - forest, Fm - devegetated, Fp - undisturbed) AFTER STANDSTILL FOR 7 DAYS AT 25 ^{o}C TO DETERMINE THE WATER CONTENT IN CORRESPONDING STATE

That water content was determined by the following equation:

$$WCSSinCS = 100\ (V_{sed} - m_s f / \rho_s)/(V_{sed} - m_s f/\rho_s + m_s f)$$

where *WCSSinCS* is given in unit g in 100 g suspension, if the measured mass of soil m_s is given in g, the density of water ρ_w is ~1 and that of solid ρ_s is ~2.5 g cm^{-3}, and f = (100 – water content %)/100 as explained before (Czibulya et al., 2010).

2) Rheological Measurement of Soil Suspensions

The measured soil suspensions were prepared according to the careful method elaborated by Czibulya et al. (2010), and stored in well-closed containers, providing acceptable reproducibility. The calculated amounts of soil powder (fraction <1 mm) and distilled water were mixed rigorously by glass rod and ultrasonicated; repeated for three times during about an hour, and were stored for 24 hours at 25^{o}C to reach equilibrium of the wetting, swelling and structural states before measurements.

Soil suspensions were measured under soil relevant conditions in the low shear region, regarding the protocol used by Czibulya et al. (2010). The flow and shear-time response curve measurements of soil suspensions were performed with a stress controlled HAAKE RS 150 rheometer using plate-plate sensor (PP20 Ti) and vane (FL20) at temperature 25 ± 0.1^{o}C regulated by a HAAKE C 30/K20 thermostat. The measured data were evaluated by means of the RheoWin Data Manager.

Results and Discussion

Water Content of the Soil Suspensions in Corresponding State

Fluidity of any suspensions depends highly on their water content. Therefore, the concentration of soil suspensions in rheological measurements is of crucial importance, the magnitude of measured parameters gives information about the strength of the physical network built up from soil particles in suspensions. The higher the water content is, the lower the rheological parameters are, because the number of particles in unit volume decreases and so the number of bonds between the particles, which is proportional to the shearing resistance of particle network decreases, too.

The water content of the soil suspensions in corresponding state was measured for the different samples of catenas and collected in Table 1 together with the water holding capacities of the same soil samples.

TABLE 1 COMPARING THE WATER CONTENT OF THE SUSPENSIONS IN CORRESPONDING STATE (WCSSinCS) AND THE WATER HOLDING CAPACITY (WHC) Values for Soils (the WHC* values were taken from the data base of INDEX project)

Samples Collected in 2004	*WCSSinCS* g water in 100 g suspension	*WHC** g water for 100 g soil	*WHC* g water in 100 g suspension
Puch - Agricultural (Agri)	34.8 ± 0.1	72.5 ± 1.5	42.0
Puch - Green	32.0 ± 0.3	68.0 ± 0.8	40.5
Puch - Black	29.8 ± 0.2	64.2 ± 0.8	39.1
Santomera - Forest	41.5 ± 0.6	79.1 ± 0.2	44.2
Santomera - Shrub	35.6 ± 0.1	77.1 ± 0.3	43.5
Santomera - Bare	33.3 ± 0.5	74.0 ± 4.7	42.5
Santomera - Devegetated (Fm)	35.6 ± 0.2	67.3 ± 0.8	40.2
Santomera - Undisturbed (Fp)	41.4 ± 0.1	67.1 ± 0.3	40.2
Basilicata - Bio agricultural (BA)	47.7 ± 0.2	70.5 ± 1.3	41.4
Basilicata - Conventional agricultural (CA)	60.1 ± 0.3	70.7 ± 0.7	41.4
Tuscany - Bio agricultural (BA)	41.3 ± 0.9	68.3 ± 1.0	40.6
Tuscany - Conventional agricultural (CA)	48.0 ± 0.2	69.6 ± 0.6	41.0

The *WCSSinCS* values increased parallel with the simple water holding capacity (*WHC* g water retained by 100 g soil Szegi et al., 2006; Bastida et al., 2008).

Based on the data of INDEX sample pool, it has been stated that these soil samples can be graded according to the water content of soil suspension in corresponding state:

WCSSinCS			
g in 100g suspension	<28-30	30-40	>40
water holding capacity	low	normal	high

Regarding the *WCSSinCS*, the "Black" sample of Puch could hold the lowest amount, the samples of Italy and the Spanish Forest samples the highest, and the other samples hold normal amount. Comparing the *WCSSinCS* values within the catenas, the soils of Puch catena are different in their ability to grant nutrients to vegetation in the sequence of Agri > Green > Black. The order Forest > Shrub > Bare can be found for the soils of the Santomera catena, where the effect of plant cover is investigated. The difference between the conventional (CA) and bio (BA) agriculture also manifests itself in the greater *WCSSinCS* values of CA than that of BA samples.

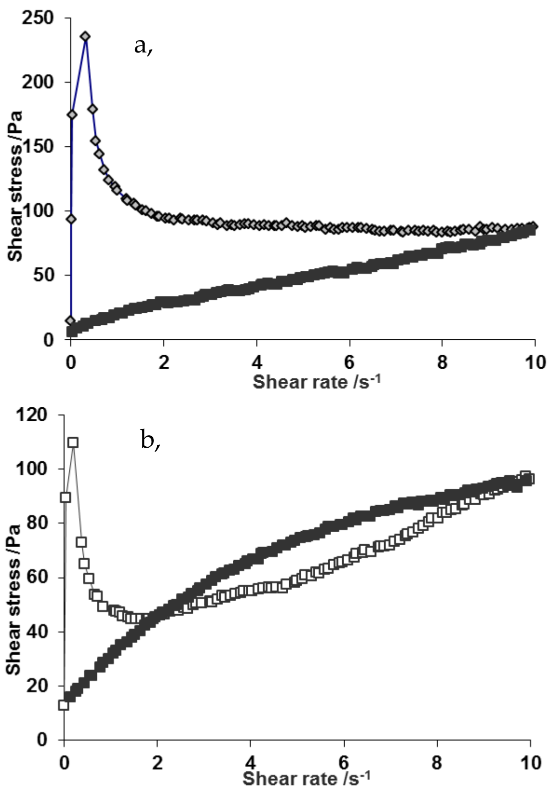

FIG. 2 a,b A USUAL THIXOTROPIC (a) AND AN UNUSUAL MIXED THIXO- AND ANTITHIXOTROPIC (b) TYPES OF FLOW CURVES MEASURED FOR SOIL SUSPENSIONS. FLOW CURVES MEASURED WITH AN INCREASING (upward curves, open symbols) THEN DECREASING (downward curves, black symbols) SHEAR RATE RAMP ARE PLOTTED

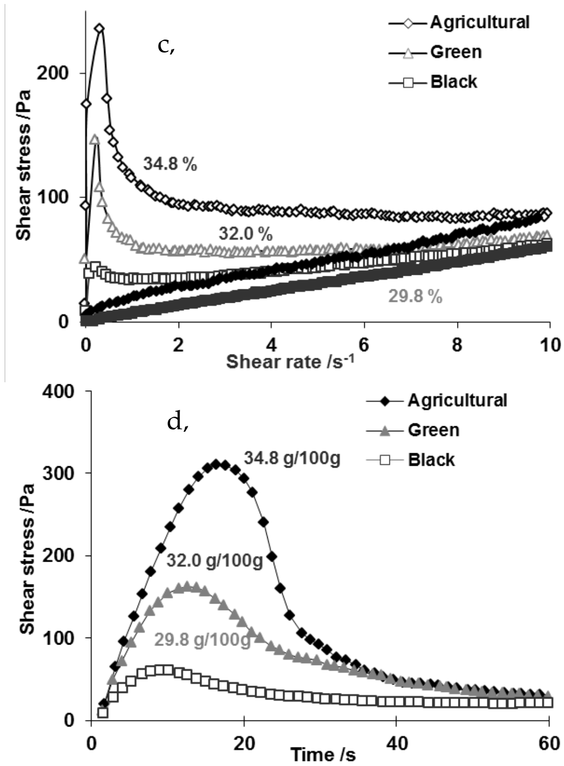

FIG. 2 c,d THE FLOW CURVES (c) AND SHEAR-TIME RESPONSE CURVES (d) OF SOIL SUSPENSIONS PREPARED FROM <1 MM SIEVED SAMPLES COLLECTED FROM PUCH EXPERIMENTAL FIELD IN 2004, MEASURED IN CORRESPONDING STATE AFTER 24 HOURS STANDSTILL AT 25^{o}C. THE WATER CONTENTS OF SUSPENSIONS ARE GIVEN IN UNIT G WATER IN 100G SUSPENSION (g/100g in figure)

Rheology of Soil Suspensions in Corresponding State

The viscoplastic type of flow was characteristic of all the soil samples. The typical flow curves of soil suspensions, measured with an increasing (upward curves, open symbols) then decreasing (downward curves, black symbols) shear rate ramp, are shown in Fig. 2. The type of flow curve (a) measured usually in the comparable soil suspensions was pseudoplastic and significant thixotropy was experienced in almost all cases. The initial maximum is expressed. This shape does not frequently occur in the suspension rheology (Barnes, 1997) apart from soil suspensions and the suspensions modelling soils in which the rate of Ca^{2+} ion and the organic matter content is adequate (Bronic and Lal, 2005; Majzik and Tombácz, 2007). This particular shape of thixotropy appears in the case of loose aggregates with medium adhesion which develop slowly in time. A kind of antithixotropy appeared in the suspensions of Italian soil samples as shown in the Fig. 2. (b) which were especially sensitive for handling.

The initial maximum, the maximum of flow curves can be determined; and the thixotropic loop area can

TABLE 2 THE EXPERIMENTAL DATA FOR MISMANAGEMENT CATENA SAMPLED IN A LONG TERM EXPERIMENTAL FIELD CLOSE TO PUCH (Germany) IN 2004. (*H_2O* is the water content of suspensions, τ_0 is the absolute yield value calculated from the shear-time response curves, τ_{inimax} is the initial maximum, A_{thixo} is the thixotropic loop area, τ_B the extrapolated yield value and η_{pl} is the plastic viscosity evaluated from the flow curves of suspensions. *Chum* is the humic substances carbon and *TOC* is the total organic carbon; the values were taken from the data base of INDEX project.)

Data of suspensions sampled in 2004	H_2O / g in 100 g suspension	τ_0 / Pa	τ_{inimax} / Pa	A_{thixo} / Pa s^{-1}	τ_B / Pa	η_{pl} / Pa s	*Chum* / mg kg^{-1}	*TOC* / g in 100 g soil
Puch-Agri	34.8$\pm$0.1	311.0$\pm$1.0	290.7$\pm$64.6	562.7$\pm$85.7	6.6$\pm$4.7	5.8$\pm$1.2	3242.8$\pm$8.1	1.22 $\pm$ 0.1
Puch-Green	32.0$\pm$0.3	171.3$\pm$8.5	150.3$\pm$3.5	231.3$\pm$12.5	6.2$\pm$2.5	5.0$\pm$0.9	2774.5 $\pm$20.4	0.73 $\pm$ 0.0
Puch-Black	29.8$\pm$0.2	74.3$\pm$13.0	38.6$\pm$1.5	146.0 $\pm$1.0	1.5$\pm$0.3	5.8$\pm$0.0	2531.2$\pm$20.7	0.75 $\pm$ 0.1

be calculated by RheoWin Data Manager. The extrapolated yield value (τ_B) and the plastic viscosity (η_{pl}) were calculated from the downward curves over the plastic flow range according to the Bingham model ($\tau = \tau_B + \eta_{pl}\,(d\gamma/dt)$). Significant thixotropy was experienced in almost all cases, but Italian suspensions showed a mixed feature of thixotropy and antithixotropy (Fig. 2 b curve).

Mismanagement Catena Samples from Puch

The effects of wrong agricultural managements on soil quality were investigated in Puch experimental plots. There was about 5% difference in water content of soil suspensions determined from the equilibrium sediment volume as shown in the glass tubes in Fig. 3.

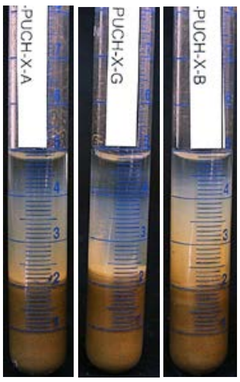

FIG. 3 GLASS TUBES CONTAINING THE EQUILIBRIUM SEDIMENTS PREPARED FROM SOIL SAMPLES FROM THE LONG TERM EXPERIMENTAL FIELD IN PUCH (A - agricultural, G - green and B - black fields) AFTER STANDSTILL FOR 7 DAYS, AT 25 ^{o}C

The flow and the shear-time response curves of soil suspensions which can be seen on Fig. 2 c and d, respectively, were evaluated (Barnes, 1997; Barnes and Nguyen, 2001) and the data which give information about the shear tolerance of the dense soil suspensions, are summarized in Table 2.

The maximum of shear-time response curves, the absolute yield value changes parallel with the initial maximum of flow curves.

Comparing the determined rheological parameters, the same order Black < Green < Agri can be seen in the case of the suspensions of year 2004. The strongest structure could be formed in the suspension Agri and so this could tolerate the highest shear stress. All the rheological values measured for the suspensions of 2005 were higher than that of the 2004 samples due to the 3-4 percentage water content difference, and the data of Green and Black suspensions sampled in 2005 became inverted. It was proved that a decrease in water content was accompanied by an exponential increase in initial stress (Czibulya et al., 2010) similar to the yield stress, shear modulus and viscosity of all the soils tested before (Ghezzehei and Or, 2001).

It is generally admitted that the soil quality can be graded by its organic matter (*OM*) content. Some values proportional to *OM* were taken from the date base of INDEX and collected in the Table 2. *Chum* (mg kg^{-1}) is the humic substances carbon determined in a filtered and centrifuged 1:20 (solid:liquid) sodium pyrophosphate extract (pH 9.8) with a Shimadzu TOC5050A Total Organic Carbon Analyzer. *TOC* (g in 100 g soil) is the total organic carbon determined by oxidation with $K_2Cr_2O_7$ in an acidic medium and evaluating the excess of dichromate with $(NH_4)_2Fe(SO_4)_2$ (Bastida et al., 2008).

It can be seen that the mismanagement disturbs the soil quality, the organic matter contents of mismanaged fields decreased in the sequence of Agri > Green > Black similarly to the lowering of their rheological parameters which are characteristic of the strength of physical network, i.e., the grade of structural degradation (Akagi and Zsolnay, 2008). This state can be argued by comparing the absolute yield value of the soil suspensions in corresponding state with the total organic carbon and also the humic substances carbon content of the soil samples as seen in Fig. 4. Similar to the absolute yield values (measured by vane method (Barnes and Nguyen, 2001)) both the humic substances carbon and the total organic carbon increase with the water content of the suspension. The absolute yield value is very sensitive to the changes in soil quality; supposedly it can indicate the structural degradation earlier than the *OM* parameters. A field device (e.g., the Pocket Vane

Tester of Eijkelkamp Co.) can be used for early indication, since the parameter measured easily by this handy tool is comparable with the above mentioned one (Czibulya et al., 2010).

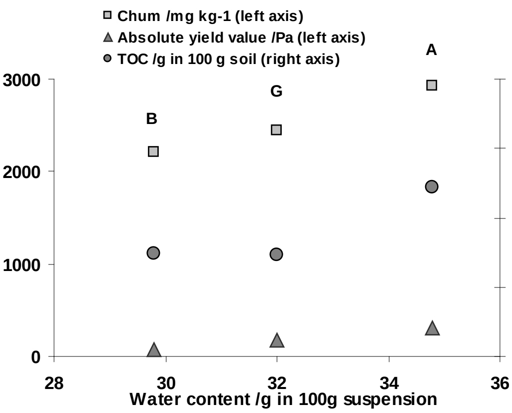

FIG. 4 COMPARISON OF TOTAL ORGANIC CARBON (*TOC*, g/100 g in figure means g in 100 g soil), HUMIC SUBSTANCES CARBON (*Chum*, mg kg^{-1}) AND THE ABSOLUTE YIELD VALUE (Pa) FOR SOIL SUSPENSIONS IN CORRESPONDING STATE AS A FUNCTION OF WATER CONTENT IN SUSPENSIONS. THE DATA OF SOIL SAMPLES FROM EXPERIMENTAL FIELD IN PUCH (A - agricultural, G - green AND B - black fields) IN 2004 ARE PLOTTED

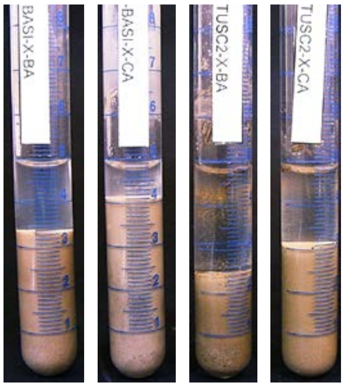

FIG. 5 GLASS TUBES CONTAINING THE EQUILIBRIUM SEDIMENTS OF SOIL SAMPLES FROM CULTIVATION EXPERIMENTS IN BASILICATA (1st and 2nd tubes) AND TUSCANY (3rd and 4th tubes) (BA – bio agriculture, CA – conventional agriculture) AFTER STANDSTILL FOR 7 DAYS AT 25^{o}C

Cultivation Catena Samples from Basilicata and Tuscany

The effect of conventional and bio agriculture (CA and BA, respectively) on soil structure was investigated. The water contents of suspensions in corresponding state are very different as seen the obvious differences in equilibrium sediments in Fig. 5. The water contents of CA samples are extreme high especially that of Basilicata sample (2nd tube in Fig. 5), so these are very good in water retention. We have to note the high salt content of these soils, which may be the reason of their enhanced moisture holding capacity.

The shear-time response and the flow curves of soil suspensions with relatively high water content were measured. The types of flow curves for conventional and bio agriculture samples were different from that experienced in any other soil suspensions investigated within INDEX project. The suspensions either show low thixotropy or even antithixotropy appears as measured in the suspensions of Tuscany (on Fig. 2 b). The structure of these suspensions is more sensitive to shear than that of Basilicata. The rheological parameters of the BA and CA suspensions prepared from the Basilicata and Tuscany soil samples were calculated and collected in Table 3. The suspensions from Tuscany soils are antithixotropic as the negative values of thixotropic loop area in Table 3, and do not have pseudoplastic character; therefore the Bingham yield values and the plastic viscosities cannot be calculated.

As discussed above, the water contents of CA suspensions in corresponding state are much greater than those of BA samples in both years. It can be seen that absolute yield value and initial maximum values of CA suspensions which are characteristic of the strength of physical network, are smaller than that of BA samples, i.e., the flow ability of CA suspensions is greater, in line with their higher water content (Ghezzehei and Or, 2001).

Both kinds of organic matter contents (*Chum* and *TOC* in Table 3) of soil samples from conventional cultivation are greater than those from bio agriculture. The *OM* content of soils influences not only their water holding capacity, but also the strength of particle network formed spontaneously in suspensions. The effect of humic substances may be either

TABLE 3 THE EXPERIMENTAL DATA FOR CULTIVATION CATENA SAMPLED IN THE EXPERIMENTAL FIELDS OF BASILICATA AND TUSCANY (Italy) IN 2005. (H_2O is the water content of suspensions, τ_0 is the absolute yield value calculated from the shear-time response curves, τ_{inimax} is the initial maximum, A_{thixo} is the thixotropic loop area evaluated from the flow curves of suspensions. *Chum* is the humic substances carbon and *TOC* is the total organic carbon; the values were taken from the data base of INDEX project.)

Data of suspensions sampled in 2005	H_2O / g in 100 g suspension	τ_0 / Pa	τ_{inimax} / Pa	A_{thixo} / Pa s^{-1}	*Chum* / mg kg^{-1}	*TOC* / g in 100 g soil
Basilicata-Bio agricultural (BA)	44.5 ± 0.4	99.3 ± 5.2	50.0 ± 0.6	121.7 ± 9.2	2014.5 ± 9.3	1.3 ± 0.03
Basilicata-Conv. agricultural (CA)	56.3 ± 0.6	73.7 ± 0.6	39.1 ± 5.8	99.2 ± 15.0	2345.6 ± 131. 2	1.6 ± 0.1
Tuscany- Bio agricultural (BA)	34.4 ± 0.1	170.7 ± 15.6	113.9 ± 20.6	-122.3 ±11.9	1460.7 ± 79.2	1.3 ± 0.2
Tuscany- Conv. agricultural (CA)	44.3 ± 0.1	112.4 ± 11.7	86.2 ± 7.3	-70.5 ± 96.0	2039.7 ± 227.3	1.8 ± 0.1

TABLE 4 THE EXPERIMENTAL DATA FOR PLANT COVERAGE CATENA SAMPLED IN SANTOMERA (Spain) IN 2004. (*H_2O* is the water content of suspensions, τ_0 is the absolute yield value calculated from the shear-time response curves, τ_{inimax} is the initial maximum, A_{thixo} is the thixotropic loop area, τ_B the extrapolated yield value and η_{pl} is the plastic viscosity evaluated from the flow curves of suspensions. *Chum* is the humic substances carbon and *OM* is the organic matter of the soil samples, calculated from *TOC* values multiplied them by the factor 1.72 (Bastida et al 2008); the values were taken from the data base of INDEX project

Data of suspensions sampled in 2004	H_2O / g in 100 g suspension	τ_0 / Pa	τ_{inimax} / Pa	A_{thixo} / Pa s^{-1}	τ_B / Pa	η_{pl} / Pas	*Chum* / mg kg^{-1}	*OM* / g in 100 g soil
Santomera-Undisturbed (Fp)	41.4±0.1	432.7±8.6	1197.7±49.6	3706.0±240.2	201.0±15.9	11.3±0.9	8041.3±117.6	6.9±0.0
Santomera-Forest	41.5±0.6	385.0±30.5	832.0±59.1	2677.7±907.3	45.2±6.2	6.1±0.3	5323.3±33.8	6.7±0.2
Santomera-Devegetated (Fm)	35.6±0.2	322.7±15.8	793.3±78.9	1857.0±288.7	64.0±1.4	9.4±0.6	5743.3±487.0	5.2±0.4
Santomera-Shrub	35.6±0.1	152.0±5.3	288.0±71.7	575.3±116.6	12.8±4.2	3.7±1.0	1839.3±95.5	2.0±0.2
Santomera-Bare	33.3±0.5	218.0±34.8	161.0±47.8	297.0±78.6	9.5±1.3	3.4±0.4	1189.3±16.0	1.5±0.3

dispersing or aggregating. It can liquefy soil suspensions in the absence of structure building cations. However, a stronger structure can build, if both humic substances and Ca^{2+} are present especially in optimal ratio (Majzik and Tombácz, 2007). In the Italian samples with high salt content, the liquefying effect becomes stronger than the solidifying effect, since Na^+ is a dispersive agent resulting directly in the break up of aggregates (Bronic and Lal, 2005). The higher organic matter content in CA soils without the adequate amount of calcium, and the extreme high water content both liquefy the suspensions. The structure of bio agricultural suspensions seems to be stronger than those of suspensions from conventional cultivation probably because of their lower *OM* contents and greater suspension concentration.

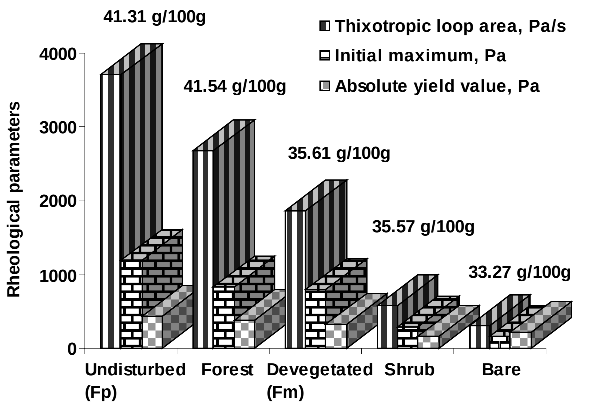

FIG. 6 COMPARING SOME RHEOLOGICAL PARAMETERS OF SOIL SUSPENSIONS ARRANGED IN A ROW AS THEIR WATER CONTENT (given above the columns) DECREASED. SOIL SAMPLES FROM SANTOMERA CATENA IN 2004 ARE SHOWED

Santomera Catena, the Effect of Plant Coverage

The effects of plant cover were investigated in the case of Santomera catena sampled in 2004 and 2005. The shear-time response and flow curves of suspensions prepared from <1 mm sieved soil samples were measured in corresponding state after 24 hours standstill at 25°C. The type of flow curves was pseudoplastic and the thixotropy was pronounced as usual in soil suspensions. The rheological parameters are collected in Table 4 and compared in Fig. 6.

The measured rheological data increased with increasing water content of the suspensions in corresponding state, which is just the opposite as expected from the basic principles of suspension rheology (Barnes et al., 1989).

In spite of their high water content, the shear tolerance of the suspensions was also high. The higher the plant cover is, the stronger the particle network is formed spontaneously in the suspensions, which together with the higher water holding capacity results in better soil quality.

It has to be noted that the water content of suspensions in corresponding state is some percentage lower in year 2005 than that in 2004 (except sample Santomera Forest), which causes significant, more than 5 times increase in strength of suspensions as expected considering the definite increase in the number of binding points in unit volume of particles network with increasing suspension concentration.

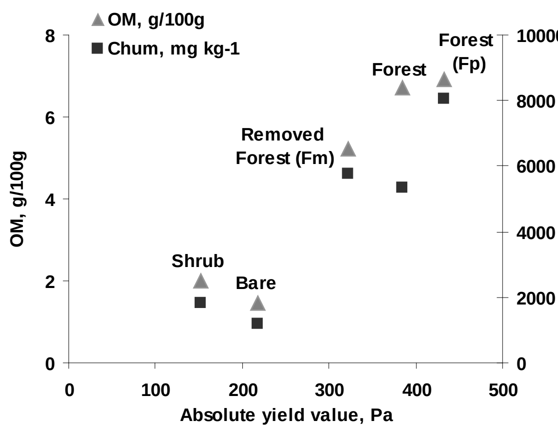

FIG. 7 THE EFFECT OF ORGANIC MATTER CONTENT ON THE SHEAR TOLERANCE OF SOIL SUSPENSIONS IN CORRESPONDING STATE; THE ORGANIC MATTER CONTENT (*OM*), HUMIC SUBSTANCES CARBON (*Chum*) AS A FUNCTION OF THE ABSOLUTE YIELD VALUE ARE SHOWN. THE DATA OF 2004 SAMPLES FOR SANTOMERA CATENA ARE PLOTTED

The data for 2004 sampling years are listed according to the decreasing plant coverage in Table 4. Both the organic matter content and the humic substances carbon decrease in the same order from top to bottom. The relation between the plant density of soils and the *OM* content is inherent, since soil organic matter originates naturally from plants. The interesting fact is that strength of suspensions, their resistance against shear change in parallel with their *OM* content for all Santomera samples without exception. This trend for the absolute yield values is shown obviously in Fig. 7.

As discussed above, the effect of humic substances may be either dispersing or aggregating. In spite of the fact that water content of suspensions measured in corresponding state increases with increasing *OM* content, the significant solidification of suspensions with increasing humic substances content can be explained, if the presence of structure building cations is assumed. The mineral composition data of these soils show about 50% total carbonate and the available Ca^{2+} is also significant (0.075 - 0.150 mol kg^{-1}), therefore the source of Ca^{2+} ions is almost unlimited to build a stronger structure of particle network in the presence of both humic substances and Ca^{2+}-ions as explained before (Majzik and Tombácz, 2007).

It can be stated that any increase in the vegetation density can improve the soil structure formed in gradual aggregation of soil particles coated by humic substances through Ca-bridges. The strongest, the most shear tolerant soil suspension was prepared from the forest soil (Fp) having the densest plant coverage. The difference between this soil and the devegetated one can be indicated by the absolute yield values, as it was possible by humo-enzime values in the article Masciandaro et al. (2008). The strength of structure depends highly on the organic matter : Ca^{2+} ratio of the soil sample. In the case of Santomera catena samples the adequate calcium content is available for structure formation through metal ion bridges (Majzik and Tombácz, 2007). The bivalent Ca^{2+} ions improve soil structure though bridging with clay particles and soil organic carbon (Bronic and Lal, 2005).

Conclusions

In the present work, the different kinds of catenas as experimental field for mismanagement, biological and conventional agricultural fields and the effect of plant cover were studied. Rheological parameters of suspensions containing as much water as equilibrium sediment can retain during long standstill (Czibulya et al., 2010) were determined and compared with other chemical parameters, mainly with those related to the organic matter content of soils *TOC*, *OM*, *Chum* values.

Under soil relevant conditions, the colloidal parameters govern rheological behavior of suspensions. Any change even slight modification in the surface layer of soil particles (Johnston and Tombácz, 2002) or in the surrounding aqueous phase, i.e. in the soil solution, should become visible in the low shear measurements. The soils from each catena are at different stages of either degradation or cultivation, which affects the surface properties of particles and the composition of aqueous interfaces. The flow ability of soil suspensions in corresponding state was influenced by liquefying and solidifying effects:

1) The water content has inherent relation to the density of particle network (i.e., the number of binding points in unit volume). The lower the value is, proportional to the *WHC* of soils, the denser the suspension is and so the stronger the particle network is, i.e., the shear tolerance or in other words the resistance against shear is higher in more concentrated suspensions. The soils having higher *WHC* are better for plant coverage; however, the higher water content liquefies suspensions.

2) The fluidity of suspensions depends not only on the number of flow units but also the strength of bonds between them. In the case of soils, humic substances and Ca^{2+} ions are considered as cementing agents. The strength of bonds is inherently connected with *OM* content of soils and the specific ions in soil solution (Holthusen at al., 2012). The presence of cementing cation like calcium is essential for the formation of bridges between mineral particles and between organic matter and mineral particles, too (Bronic and Lal, 2005; Majzik and Tombácz, 2007). Only the dispersing effect of relatively high *OM* content in the Italian soils came out and suspensions were liquefied for lack of Ca^{2+} ions, while gradual solidification of suspensions were observed with increasing amount of humic substances in Spanish soils due to the unlimited source of Ca^{2+} from carbonate rock in the field.

3) The ionic composition of soil solutions can influence the water holding capacity; probably the high salt content of soil enhances the *WCSSinCS* as seen Italian samples. However, strengthening effect of salt is not certain, depending on whether the salt content is below or above its coagulation value, since only the coagulated network of particle is strengthened.

The negative influence of mismanagement on soil quality, the degradation effect of conventional and bio agriculture could be differentiated on the basis of suspension rheology. For general use, the pocket vane tester is advised, as it seems to be also a good tool for monitoring structural degradation of a given land in time as suggested before (Czibulya et al., 2010).

ACKNOWLEDGMENT

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Effect of Modified Atmosphere Packaging on Shelf Life of Sapota Fruit

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Abstract

Freshly harvested and uniformly matured sapota fruits (cv *Kalipatti*) were precooled at 10°C for 1 h and pretreated with 200 ppm benomyl for 5 min. The fruits were treated with active modified atmosphere packaging (MAP) in 25 μ and 40 μ LDPE bags with 5% O_2 + 5% CO_2 and 5% O_2 + 10% CO_2 gas concentration and stored at 6 ± 1°C and 11 ± 1°C. Physical, biochemical and sensory characteristics of sapota fruit were assessed at 7 days intervals. It was found that sapota fruit was stored up to 35 days at 11^{0}C in 25 μ LDPE bags and fruits ripened within the package during storage. It was concluded that the shelf life of sapota fruit could be increased up to 49 days by packaging in 25 μ LDPE bags with gas concentration 5% O_2 + 10% CO_2 and stored at 6°C with another three days to become fully ripe under ambient conditions. Fruits packed in 40 μ LDPE bags did not ripen properly at both the storage temperature.

Keywords

Sapota; MAP; LDPE; Gas Concentration; Shelf Life; Storage

Introduction

Sapota or sapodilla (Manilkara Achras), popularly known as chiku, is an important fruit in tropical region. The area under sapota in India was 0.16 million hectares with annual production of 1.4 million MT during the year 2010-11. During the same period, 2039 MT of sapota fruits were exported, which earned Rs.3.53 crores (Anon, 2011). Sapota being climacteric fruit, has very short shelf life and marketing of fresh fruits to distant places is very difficult. The short harvesting season, limited domestic demand and improper storage facility create glut in the market and consequently loss to the fruit growers. Due to its short shelf-life, in India as much as 30-35 per cent of fruits perish as post harvest losses during harvesting, storage, grading, transportation, packaging and distribution thus incurring a precious loss about Rs. 70,000 crores is in terms of not only revenue but also health as fruits play a vital role in human nutrition (Khurana and Kanawjia, 2006). Food packaging is a critical technology addressing the ever-increasing demands for convenience, freshness, ease, shelf life, safety, and security of food products. Packaging is an integral part of food processing to assemble the produce in convenient units and to protect the foods from physiological, pathological and mechanical deterioration in marketing channels and retains attractiveness. It provides a barrier between the food and the environment, controls light transmission, the transfer of heat, moisture and gases and movement of microorganisms or insects; and reduces distribution cost and maintains the quality of fresh and processed products during storage. Packaging is a very important link between the grower, processor and consumer. MAP is known to extend the shelf life of fresh produce by retarding the physiological metabolism leading to senescence by the increased CO_2 and decreased O_2 concentrations in the storage atmosphere, slowing down the rate of respiration, C_2H_4 biosynthesis, metabolic processes and its action; retains chlorophyll, textural quality and sensory quality of the fruits subsequently helping in reducing microbial contamination and by creating high humidity resulting in less moisture loss and better quality retention (Rai *et al*., 2002). Many researches have also reported that MAP maintained physical, biochemical and sensory characteristics of the fruit (Jacomino *et al*. 2005; Xihong *et al*. 2011; Giacalone and Chiabrando 2013). However, improper use of MAP or the use of an inappropriate MA film, gas concentration and storage temperature could result in anaerobic conditions, leading to product spoilage.

Materials and Methods

Freshly harvested and fully matured sapota fruit cv *Kalipatti* at colour breaker stage was procured from farmer's orchard for the experimental purpose. The scurf sticking to the skin of the fruits was removed by rubbing with gunny bag and immediately precooled in a cold chamber at 10°C with 85-90% RH for 1 hour to remove the field heat. The precooled fruits were graded on the basis of weight (85-90 g) to maintain homogeneity. The diseased, bruised and insect infected fruits were separated out. Then the selected fruits were thoroughly washed with clean water to remove dirt and dust particles. The graded fruits were pretreated with benomyl (200 ppm) for 5 min to prevent fungal infection. The antifungal solution was prepared by dissolving 4 g of benomyl (50% w.p.) in distilled water and final volume was made up to 10 litre by adding additional water. After drying under shade, four fruits together (350 g) were sealed in a LDPE bag of 150 x 225 mm size and 25 μ and 40 μ thickness by keeping 8-10 cm headspace with gas proportions of 5% O_2 + 5% CO_2 and 5% O_2 + 10% CO_2 by MAP system (Elixir technologies, Bangalore). The samples were stored at 6 ± 1°C (90-95 % RH) and 11 ± 1°C (85-90 % RH) storage temperature.

Details of Treatment

1. CO_2 concentration (G): G_1 - 5% and G_2 - 10%
2. Thickness of LDPE bags (P): P_1 - 25 μ and P_2 - 40 μ
3. Storage temperature (T): T_1 -6 °C and T_2 -11°C

The physical, biochemical and sensory characteristics of the sapota fruits were analyzed at 7 days interval during storage. The weight loss was determined by recording the initial weight of fruits prior to packaging. Pulp to peel ratio was measured by ratio of weight of pulp to weight of peel of the fruit. The firmness of the fruit was measured with the help of texture analyzer (TA-XT2i, Stable Micro Systems, UK) having 50 kg load cell capacity and 5 mm stainless steel probe. Specific gravity of fruit was determined by liquid displacement method as suggested by Mohsenin (1986). Visually sound fruits without any shrinkage and deterioration were considered as marketable fruits. Total soluble solids was measured by hand refractometer (range 0-32%) and corrected at 20°C. Total sugar was determined by phenol sulphuric acid method as reported by Sadasivam and Manikam (1996), while ascorbic acid and titratable acidity was estimated as reported by Ranganna (2000). Sensory characteristics *viz*., appearance, pulp colour, flavour, taste and over all acceptability was evaluated during storage after ripening the fruits at room temperature (30 ± 2°C) for 72 hours. Sensory characteristics of ripe fruits were evaluated by a panel of 10 judges using 9 point hedonic scale (Amerine *et al*., 1965). The experiment was carried out considering Factorial Completely Randomized Design with three replications (Panse and Sukhatme, 1985) and conducted for two years and pooled analysis was carried out.

Results and Discussion

Physical Parameters

1) Physiological Loss in Weight (PLW, %)

From the Fig. 1, it can be observed that weight loss increased with increase in storage period. Weight loss increased with decrease in thickness of LDPE bag and CO_2 concentration, while it increased with increase in storage temperature. It was apparent from the figure that minimum weight loss was recorded in treatment combination $P_2G_2T_1$ (0.63%) on 49 days and maximum in $P_1G_1T_2$ (1.96%) on 42 days of storage. It might be due to less respiration and transpiration loss of moisture from the fruits at low storage temperature (6°C) in low permeable film (40 μ) with higher CO_2 concentration (10%). A similar finding for PLW was also reported by Gutierrez *et al.* (2002) in guava and Pala *et al*. (1992) in sweet cherries during storage. The analysis of data revealed that effects of thickness of LDPE bag, gas concentration and storage temperature was found significant during entire storage period. Interaction between P*G*T was found insignificant while in pooled analysis, interaction of P*G was found significant. Fruits packed in 25 μ LDPE bags and stored at 11°C over-ripened on 42 days of storage and discarded from the analysis.

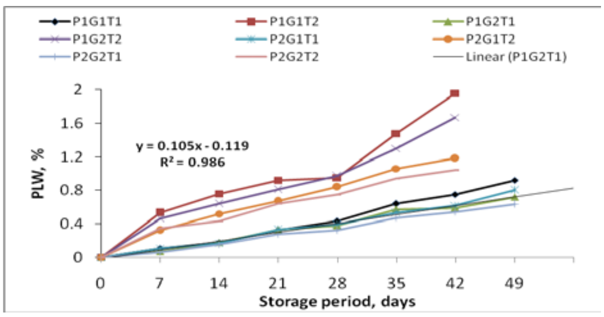

FIG. 1 EFFECT OF DIFFERENT MAP ON PLW IN SAPOTA FRUIT DURING STORAGE

2) Pulp to peel ratio:

It was evident from the Fig. 2 that pulp to peel ratio increased with increase in storage period. Rate of increase in pulp to peel ratio slowed down by increase in thickness of LDPE bag and CO_2 concentration and decrease in storage temperature. Minimum pulp to peel ratio *i.e.* 7.96 was observed in $P_2G_2T_1$ at the end of 49 days of storage period and maximum (9.72) was found in $P_1G_1T_2$ on 42 days of storage. This might be attributed to the development of optimum storage condition which was inhibited to ripening process in the fruit. Similar findings for pulp to peel ratio were also reported by Gutierrez *et al.* (2002) in guava and Pekmezci *et al.* (2003) in apple.

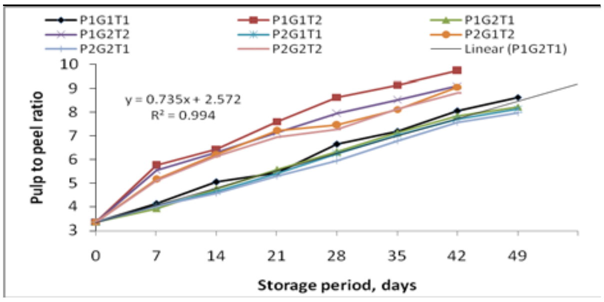

FIG. 2 EFFECT OF DIFFERENT MAP ON PULP TO PEEL RATIO IN SAPOTA FRUIT DURING STORAGE

3) *Firmness (mm)*

From the Fig. 3, it can be seen that irrespective of treatment, firmness decreased with storage period as penetration increased. Firmness of the fruits decreased with decrease in thickness of LDPE bag and CO_2 concentration and increase in storage temperature. Minimum penetration was observed in (15.0 mm) at the end of 49 days of storage and maximum (26.0 mm) was observed in treatment $P_1G_1T_2$ on 42 days of storage. The firmness retention in $P_2G_2T_1$ during storage might be due to less breakdown of insoluble protopectin into soluble pectin or by less cellular disintegration during storage (Mahajan *et al.,* 2008). The decrease in firmness during storage was also reported by Issak *et al.* (2006) in banana and Lalel *et al.* (2005) in mango.

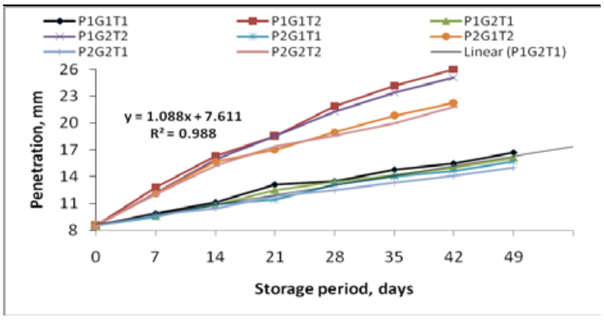

FIG. 3 EFFECT OF DIFFERENT MAP ON PENETRATION IN SAPOTA FRUIT DURING STORAGE

The effect of temperature was found significant during entire storage while the effect of thickness of LDPE bag, and gas concentration was found significant for most of the cases.

4) *Specific Gravity*

It was clear from the Fig. 4 that specific gravity of sapota followed a declining trend with advancement in storage period. The rate of decrease in specific gravity increased with decrease in thickness of LDPE bag and CO_2 concentration and increase in storage temperature. Maximum specific gravity *i.e.* 1.026 was recorded in $P_2G_2T_1$ at the end of 49 days of storage period and minimum was observed in $P_1G_1T_2$ (0.958) on 42 days of storage. It might be attributed to the development of optimum storage condition which was inhibited to the ripening process in the fruit. These results are in agreement with reported by Singh and Pal (2008) in guava.

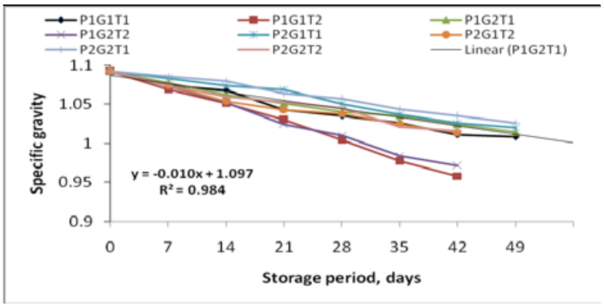

FIG. 4 EFFECT OF DIFFERENT MAP ON SPECIFIC GRAVITY OF SAPOTA FRUIT DURING STORAGE

5) *Marketable fruits (%):*

From the Table 1, it was obvious that marketable fruits decreased with advancement of storage period. At 6°C storage temperature, the maximum (100%) marketable fruits were recorded in treatments $P_1G_1T_1$, $P_1G_2T_1$ and $P_2G_1T_1$ up to 49 days of storage period. It was observed that as the storage temperature increased, marketable fruits decreased.

TABLE 1 EFFECT OF DIFFERENT MAP ON MARKETABLE FRUITS OF SAPOTA FRUIT

Treatments	Storage period, days						
	7	14	21	28	35	42	49
$P_1G_1T_1$	100	100	100	100	100	100	100
$P_1G_1T_2$	100	100	100	100	80	37.5	
$P_1G_2T_1$	100	100	100	100	100	100	100
$P_1G_2T_2$	100	100	100	100	85	43.75	
$P_2G_1T_1$	100	100	100	100	100	100	100
$P_2G_1T_2$	100	100	100	100	95	87.5	
$P_2G_2T_1$	100	100	100	100	100	100	91.66
$P_2G_2T_2$	100	100	100	100	85	81.25	

The minimum marketable fruits (37.5%) were found in treatments $P_1G_1T_2$ followed by in treatment $P_1G_2T_2$ (43.75%) on 42 days of storage period. At 11°C storage temperature, marketable fruits were observed maximum in gas concentration 5% O_2 + 10% CO_2 for 25 μ LDPE bags and reverse trend was observed for 40 μ LDPE bags during storage. Fruits packed in 25 μ LDPE bags and stored at 11°C over-ripened on 42 days of storage and so it was discarded from the storage.

Biochemical Parameters

1) Total Soluble Solids (TSS , Brix)

From the Fig. 5, it was evident that TSS increased gradually with the advancement of storage period. This might be due to moisture loss during storage. It can be also observed that TSS decreased after 35 days of storage for the treatments $P_1G_1T_2$ and $P_1G_2T_2$ due to over-ripening. The decrease in TSS was associated with the oxidative breakdown of sugars as a result of respiration and over ripening. Rate of increase in TSS increased with decrease in thickness of LDPE bags and CO_2 concentration. While it decreased with decrease in storage temperature. An increase in TSS during storage was also reported by Gutierrez *et al.* (2002) in guava and Gonzalez *et al.* (1990) in mango and avocado.

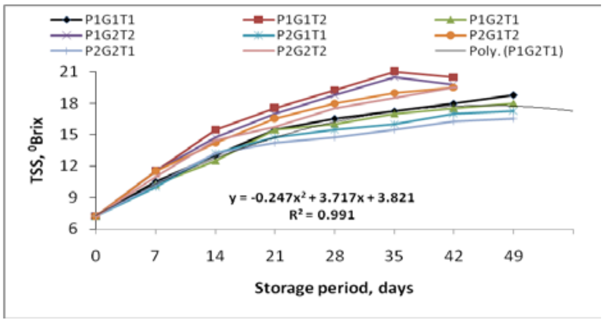

FIG. 5 EFFECT OF DIFFERENT MAP ON TSS IN SAPOTA FRUIT DURING STORAGE

Minimum TSS was observed in $P_2G_2T_1$ (16.5 ^{0}Brix) on 49 days of storage and maximum was recorded in $P_1G_1T_2$ (21°Brix) on 35 days of storage. Effect of gas concentration and interaction between P*G*T was found insignificant during entire storage period while in pooled analysis, interaction of P*G was found insignificant.

2) Total Sugar (%)

It was clear from the Fig. 6 that total sugar of the sapota fruit increased with increase in storage period. It might be due to release of sugar by the hydrolysis of polysaccharides and concentration of juice as a result of dehydration. It was also observed that total sugar decreased after 35 days of storage for the treatments $P_1G_1T_2$ and $P_1G_2T_2$ due to over-ripening. Total sugar increased in fast rate with decrease in thickness of LDPE bags and CO_2 concentration and increase in storage temperature.

Minimum total sugar was observed in $P_2G_2T_1$ (16.34%) at the end of 49 days of storage and maximum in $P_1G_1T_2$ (23.84%) on 35 days of storage. The increase in total sugars during storage is in consonance with Singh and Pal (2008) in guava.

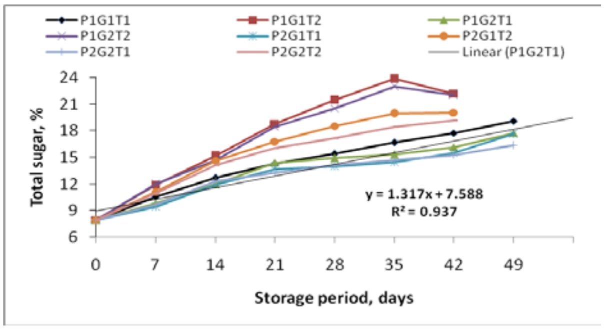

FIG. 6 EFFECT OF DIFFERENT MAP ON TOTAL SUGAR IN SAPOTA FRUIT DURING STORAGE

3) Reducing Sugar (%)

From the Fig. 7, it can be observed that reducing sugar increased with increase in storage period. It was also clear that reducing sugar of the fruits decreased after 35 days of storage for the treatments $P_1G_1T_2$ and $P_1G_2T_2$ due to over-ripening. Reducing sugar increased with decrease in thickness of LDPE bags and CO_2 concentration and increase in storage temperature. Minimum reducing sugar was observed in $P_2G_2T_1$ (1.24%) at the end of 49 days of storage and maximum in $P_1G_1T_2$ (2.64%) on 35 days of storage. A similar finding for reducing sugar was also reported by Somchai and Thitinum (2005) in guava.

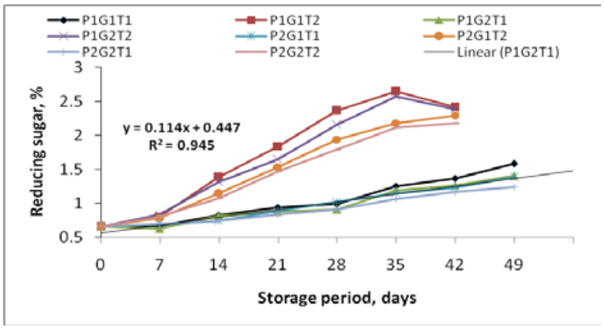

FIG. 7 EFFECT OF DIFFERENT MAP ON REDUCING SUGAR IN SAPOTA FRUIT DURING STORAGE

4) Ascorbic Acid (mg/100g)

A declining trend was observed for ascorbic acid during storage period. Ascorbic acid decreased with decrease in thickness of LDPE bag and increase in storage temperature. It was obvious from the Fig. 8 that maximum ascorbic acid was observed in $P_2G_2T_1$ (15.77 mg/100g) at the end of 49 days of storage period and minimum was found in $P_1G_1T_2$ (10.28 mg/100g) on 42 days of storage. The retention of ascorbic acid in $P_2G_2T_1$ might be attributed to the slow process of oxidation of ascorbic acid. Similar findings for ascorbic acid were also reported by Lanchero *et al.* (2007) in gooseberry and Silip and Hajar (2007) in guava. The analysis of data revealed that the effect of storage temperature was found significant and gas concentration was found insignificant during entire storage period.

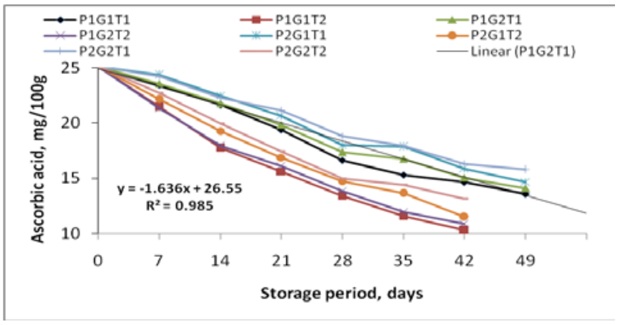

FIG. 8 EFFECT OF DIFFERENT MAP ON ASCORBIC ACID IN SAPOTA FRUIT DURING STORAGE

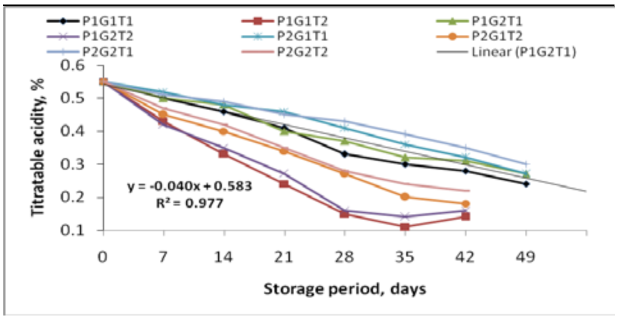

FIG. 9 EFFECT OF DIFFERENT MAP ON TITRATABLE ACIDITY IN SAPOTA FRUIT DURING STORAGE

5) *Titratable Acidity (%)*

From the Fig. 9, it was clear that titratable acidity decreased with increase in storage period, which might be attributed to the conversion of acids into sugars and by use of organic acids as respiratory substrate during storage (Gonzalez *et al.*, 1997). It can be also observed that titratable acidity increased after 35 days of storage for the treatments $P_1G_1T_2$ and $P_1G_2T_2$ due to over-ripening. The rate of decrease in titratable acidity increased with decrease in thickness of LDPE bag and CO_2 concentration and increase in storage temperature. Effects of thickness of bag and storage temperature were found significant during entire storage period, while gas concentration was found significant at the later stage. It was also apparent from the figure that maximum titratable acidity was observed in $P_2G_2T_1$ *i.e.* 0.30% on 49 days of storage and minimum was in $P_1G_1T_2$ (0.11%) on 35 days of storage. These findings for titratable acidity were in close agreement with the results reported by Noomhorm and Tiasuwan (1995) in mango and Jacomino *et al.* (2005) in guava.

Sensory Characteristics

From the Table 2, it was apparent that maximum score of overall acceptability of sapota fruit was observed in treatment combination $P_1G_2T_2$ (8.5) followed by $P_1G_1T_2$ (8.1) on 35 days and for treatment $P_1G_2T_1$ (7.3) followed by $P_1G_1T_1$ (7.1) on 49 days of storage. Maximum sensory score was observed in 25 μ LDPE bags and 5% O_2 + 10% CO_2 gas concentration. It could be attributed to the fact that lower ethylene synthesis at optimum gas concentration within package yielded better retention of fruit quality at the end of storage. Minimum score of overall acceptability of sapota fruit was observed in 40 μ LDPE bags. Low score of overall acceptability could be attributed to insufficient O_2 within package (anaerobic respiration) due to low permeability of 40 μ LDPE film. These results for sensory characteristics were in agreement with Rao and Rao (2009) in mango.

TABLE 2 EFFECT OF DIFFERENT MAP ON SENSORY CHARACTERISTICS IN SAPOTA FRUIT

Treat-ments	Storage period	Appear-ance	Pulp colour	Flavour	Taste	Overall accept-ability
$P_1G_1T_2$	35 days	8.1	8.2	8	8.2	8.1
$P_1G_2T_2$		8.4	8.4	8.5	8.6	8.5
$P_2G_1T_2$		7.1	5.5	5.3	5.4	5.8
$P_2G_2T_2$		7.1	5.7	5.5	5.5	6.0
$P_1G_1T_1$	49 days	8	6.8	6.7	7	7.1
$P_1G_2T_1$		8	7	7.1	7.1	7.3
$P_2G_1T_1$		7.8	5	4.7	4.9	5.6
$P_2G_2T_1$		8	5.1	4.5	4.5	5.5

Ripening and Decay

Fruits packed in 25 μ thickness of LDPE bags and stored at 11°C ripened within package during storage on 35 days with maximum sensory score. The fruits packed in 25 μ thickness of LDPE bags and stored at 6°C temperature ripened properly with better sensory score up to 49 days of storage. Fruits packed in 40 μ LDPE bags and stored at 6°C and 11°C did not ripen properly even after storage at room temperature for 72 h. Fruits packed in 25 μ thickness of LDPE bags and stored at 11^{0}C deteriorated on 42 days of storage due to over-ripening. Decay was not observed in the treatments $P_1G_1T_1$, $P_1G_2T_1$ and $P_2G_1T_1$ up to the end of storage.

Cost Analysis of MAP of Sapota

Cost calculation of MAP of sapota fruit is presented in Table 3. It can be observed that the total cost of packaging of sapota was estimated 4.25 Rs/Kg and net profit was found 8750 Rs/t.

TABLE 3 COST CALCULATION OF MAP OF SAPOTA FRUIT

Sr. No.	Particulars	Cost (Rs.)
1	Initial cost of MAP system	990000
2	Initial cost of cold chamber	361000
3	Fixed cost (Rs/h)	
	a. Depreciation @ 10 %	21.01
	b. Interest @ 10 % of initial cost	18.01
	c. Housing cost @ 3 %	10.12
	d. Repair & Maintainance @ 2 % of initial cost	6.75
	e. Total fixed cost	55.89
4	Variable cost (Rs/h)	
	a. Precooling	3.80
	b. LDPE bags	22.50
	c. Gas	36.22
	d. Electricity charge for MAP	6.00
	e. Labour charge	3.93
	f. Benomyl	1.91
	g. Electricity charge for Cooling	3.78
	h. Total variable cost	78.14
5	Total cost for packaging of 31.5 kg sapota = Fixed cost + variable cost	134.03
6	Total cost for packaging of 1 kg sapota	4.25
7	Market value of raw fruits (Rs/kg)	12.00
8	Total cost considering raw fruit (Rs/kg)	16.25
9	Market value after storage (Rs/kg)	25.00
10	Cost-benefit ratio	1.54
11	Net profit (Rs/kg)	8.75
12	Net profit (Rs/t)	8750

Conclusions

Sapota fruit was stored up to 35 days at 11°C in 25 μ LDPE bags and fruits ripened within the package during storage. Minimum changes in physical and biochemical parameters were found for the fruits packed in 40 μ LDPE bags and stored at 6°C storage temperature but fruits did not ripen properly. The highest sensory score was observed for 25 μ LDPE bags with 5% O_2 + 10% CO_2 gas concentrations at both the temperatures. The results revealed that the shelf life of sapota fruits could be increased up to 49 days by packaging in 25 μ LDPE bags at gas concentration 5% O_2 + 10% CO_2 and stored at 6°C with maximum sensory score. Total cost of packaging of sapota per kg was estimated Rs. 4.25 with cost-benefit ratio of 1.54.

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ICT Adoption For Bridging South African Black Farmers' Knowledge Gap

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Abstract

South Africa's post-apartheid Black farmers, commonly referred to nowadays as emerging farmers, need knowledge support to be successful in agricultural productions. An ICT-based knowledge support can assist in increasing access to their agricultural knowledge. However, bridging the knowledge gap using ICT will involve addressing ICT-related infrastructures provision challenges. In this paper, challenges hampering agricultural support provision in South Africa, particularly amongst emerging farmers in the quest to expand beyond subsistence farming, are discussed. It also addresses the need for the provision of a sustainable ICT-based knowledge support infrastructure, which would enable bi-directional interaction amongst agricultural stakeholders.

Keywords

ICT Agriculture; Agricultural Knowledge Provision; Knowledge Support; Emerging Farmers

Introduction

Addressing social issues such as food, security, poverty, unemployment, health and equity of any society or country is a challenge. Agriculture plays a crucial role in sustainable development and in hunger and poverty eradication. As indicated in the South Africa National department of Agriculture annual report (2001), about 70 percent of the rural population derived their livelihood from agriculture. The Native Land Act of 1913 barred Black people from mainstream agricultural practices and encouraged those with interest in generating income through farming to migrant farm labour. This livelihood strategy for many Black farmers, as indicated by Kinnear *et al* (sa:1) and Donovan (1994:275), was in the form of wages, pension and remittance.

Agriculture and land are well acknowledged as potential resources for poverty alleviation. Cultivating the land for productive purposes requires minimal training and education, particularly when the objectives of cultivation are not about income generation but subsistence. The mission is to achieve sustainable food security, reduce poverty and generate employment to its teaming population of unemployed, particularly the youth. The democratically elected government of South Africa has been seeking ways to promote the involvement of every willing individual in its commercial agricultural sector.

However, commercial farming is a knowledge intensive occupation. According to Omekwu (2003:445), it is a multidisciplinary or interdisciplinary field of human knowledge and endeavour through which knowledge could be drawn from pure and applied sciences, the social sciences, medicine and the arts. Mack, Ravin and Byrd (2001:1) indicated that all human work, even the most physical labour, involves cognitive capabilities.

The desire of the South African government to transform the landscape of the agricultural sector by encouraging the involvement of the Black segment of the population goes beyond the provision of land, finances, minimal training and seasonally paid mentorship; rather, a more pragmatic approach of sustainable on-the-job educational support is employed. Furthermore, to realise the transformation of Black farmers into market-oriented farming and improved their production potential, bridging South African Black farmers' knowledge gap is not an option, but a requirement.

In farming, as in any other professions, knowledge is required for its various segments and activities in order to be successful. For instance, in agricultural land preparation, seeds, seedlings, fertilizers, pesticides, harvesting, and post-harvest handling require that farmers or their employees be adequately equipped with the intellectual capability or relevant intellectual support for evaluating and incorporating new experiences and information. Intellectual capability is vital for integration of ideas, experience, intuition, skill and lessons learned; enabling the potential to create value is essential.

A vast majority of Africa's smallholding farmers, as indicated by Kelly *et al* (2003:380-383), rarely use modern inputs because a farmer who has no knowledge of inputs and who lack training on how to use them will be unlikely to adopt them. In the new dispensation of democratic South Africa, government has redressed the injustice of the past, through land redistribution programme which will enable interested Black South Africans into the mainstream of market-oriented farming.

South African farmers are globally acknowledged to be well versed in modern agriculture. However, this claim can only be attributed to a segment of South African farmers, particularly the Whites who, in decades past, enjoyed enormous support from the government; however, their Blacks counterparts were not as privileged. While the well-developed commercial agricultural sector is mainly in the hands of White South Africans, the Black farming sector, on the other hand, remains at the subsistence level in the rural areas (Kinnear et al, sa:1; Donovan, 1994:275; Lyne & Darroch, 2004:1).

The results of decades of discriminatory policies and exclusion that characterised South Africa's farming landscape, where Black South Africans were restricted to substandard education, lack of complementary agricultural support infrastructure, such as capital and extension services, are bound to be some overriding handicaps with which Black farmers will continue to struggle (Karuiki, 2004:35). As indicated by Lyne and Darrocoh (2004:2), the current political and economic crisis in Zimbabwe clearly illustrates that land redistribution without requisite intellectual capability for factors of agricultural production's utilization (Wong & Aspinwall, 2006:634) does not guarantee political stability and economic growth.

A number of techniques are currently adopted by the democratically elected government of South Africa to address the existing Black farmers' knowledge gap including: Mentorship, use of community radio, Agric television, extension services provision, workshops and conference attendance, farming group and association.

Problems: The Potential of ICTs in Enabling Seamless Agricultural Knowledge Uptake

South Africa is known worldwide for its agricultural sector with a dual structure consisting of a well-developed commercial or market-oriented farming and subsistence or risk-free farming. Those involved in market-oriented farming have gained substantial experience through formal agricultural education involving the use of scientific research-related activity and the privilege of prior experiential learning from notable commercial farms directly owned by family, relatives or friends.

The Black South African groups with subsistence farming experience are not as fortunate; they lack formal agricultural education, and their involvement in farming has been restricted to taking orders or instructions from a superior who often are from the segment with commercial farming experience. Mono-cropping farming is never an option for those involved in subsistence; besides, allocated farm land to this group of farmers is generally small; while mixed farming is considered to be more sustainable and economically viable.

Therefore, agricultural practice knowledge of these segments of farmers, particularly in market-oriented farming, is non-existent. These groups of farmers are considered nowadays as Black emerging farmers, that is, those intending to transform to commercial farming. In essence, they will have to understand how to manage farming involving one produce rather than mixed produce, manage large expanses of land with professional employees rather than those that can be subsistencely managed, relying more on scientific research reports rather depending on traditional farming approaches.

In order to provide agricultural knowledge support to these groups of emerging farmers who lack formal education and prior experiential knowledge in commercial or market-oriented farming, there must be the moving away from support approaches that could be considered as knowledge push, which do not take into consideration the farmers' background and prior learning in farming. There is the need to explore better alternatives to existing agricultural knowledge support strategies, which could enable emerging farmers' transformation and, at the same time, allow improved farmers–interaction, collaboration with all agricultural sector stakeholders, and sharing their experiences and requirements.

The problem is not that agricultural knowledge providers in South Africa are incapable of generating high-quality, innovative knowledge materials. On the contrary, there is a vast supply of potential agricultural knowledge generators, and a significant demand for their work. The problem, as indicated by Gruber, Tenenbaum and Tenenbaum (1994:3), is that the infrastructure for development and delivery of generated knowledge materials is extremely inefficient.

Knowledge materials are often developed in isolation without coordination, and media resources are seldom re-used. Therefore, traditional delivery, such as knowledge libraries, is limited by physical proximity, training seminars held in auditoriums, and hotel boardrooms. Black emerging farmers are proportionally unevenly distributed, thus hampering access to personalised, just-in-time, and on-the-job learning.

Study Objective

The main objectives of this study were to understand the existing challenges hampering the transformation of South Africa's emerging farmers into market-oriented farming and to evaluate the overall performance of using traditional agricultural knowledge diffusion approaches as a means of providing agricultural knowledge support, particularly to those in the rural community, in order to enhance sustainability. The study also aimed to evaluate how ICT could be implemented to provide the needed agricultural knowledge support infrastructure for farmers' transformation.

ICT Usage for Knowledge Support Provision

ICT has revolutionised the way we live, communicate, share and re-use knowledge. The interactive process of making the right information or knowledge available in a comprehensive manner to people of common interest is known as knowledge sharing that as indicated by Vikas (2002:2) can take place at all levels. However, to enhance equitable sharing, knowledge must be placed in the public domain to discourage its exploitative use by only a handful of users.

Considering the importance of an effective and efficient means of information and knowledge transference, communication and distribution, and in order to promote the continuous improvement of competitiveness and leadership in information technologies and skills, ICT can be applied to effectively and efficiently support the further development of the agricultural sector in South Africa.

ICT is considered as the most viable platform alternative that may be used to enable South Africa's Black farmers' transformation because of various services and tools that could be made available when providing required personalised support in the agricultural domain. The continued evolution of the internet provides a platform for individuals to establish interactions with remote knowledge support systems which are able to recognise their personal attributes for services and information or knowledge delivery.

Multimedia resources and a host of applications that could be used to provide the required agricultural knowledge in a synchronous and asynchronous mode, affording the user the opportunity to learn and respond to issues without the time constraints make ICT a viable platform; which happens to be the bane of the traditional agricultural knowledge support.

The synchronous or asynchronous resources of ICTs for knowledge support may be independently applied without being integrated, depending on the user's preference. However, the integrations of both synchronous and asynchronous mode set of applications are more acceptable today for knowledge support. A platform of tools where dynamic services could be provided 24/7, affording personalisation, enables the users to learn at their own pace with additional options of storage for future use. Meanwhile, it is equally possible for any willing users to share their personal experiences and suggestions with others online.

The application of ICT for agricultural knowledge support is a paradigm shift from the tradition of using radio, television, farmer days' shows, board room conferences/workshops/symposia, printed media and the likes where knowledge support services are often restricted by location, duration, cost and space. The heterogeneous nature, as indicated by Van der Walt and Coetzee (2003:1), and the specificity of knowledge required by Black farmers who often feel difficult to cluster together, render the use of community radio inappropriate and inefficient. Radio is, however, commonly regarded as cost effective, considering the reach of its coverage. But knowledge support is not only about the breadth and width of coverage; it is also about the value, adoptability, relevance to current activities, and usefulness of the disseminated knowledge by the end user.

The Study Context

The research approach was designed to understand existing agricultural knowledge support of the Black South African farmers commonly referred to nowadays as "emerging farmers" to denote their involvement in commercial or market-oriented farming in contrast to their previous subsistence farming practices. Participants were selected using purposeful, or judgemental, and snowballing sampling approaches.

The participating Black farmers have minimum of secondary education, but those without basic education in agriculture have been excluded in agricultural education prior to 1994. Those involved are able to interact with technology, such as using internet browsers, emailing and instant messaging. It was also pertinent that those with basic agricultural education were excluded because of their capability to understand agricultural terms required for solving farm challenges and interpreting agricultural research results that people without agricultural education will require further explanation from established commercial farmers or knowledge support service providers.

Knowledge support service providers to this group of emerging farmers were also included as participants in order to understand challenges they encountered in their bid to provide the needed support to these farmers. Knowledge support service provider participants were identified by the participating emerging farmers; because the researcher wanted to ensure that knowledge support services providers have been directly involved with emerging farmers.

Data Collection

The qualitative interpretive research approach was adopted because it enabled the researcher to collect empirical data directly from the subjects themselves while sitting with the respondents presenting their views, perceptions and detailed expectations. The strategy contended that knowledge and understanding are subjective and ideographic, and truth is context-dependent and can only be obtained after the entry into the participants' reality.

The researcher was able to observe subtle communications and other events that were not anticipated, which added credibility to the data, but could have been difficult to noticed, if other approaches had been utilized (Babbie,2005:296). The study adopted a grounded theory research design.

A grounded theory research design, as indicated by Babbie (2005:304), attempted to derive theories from an analysis of patterns, themes, and common categories discovered in data sets, enabling the researcher to be scientific and creative at the same time. In other words, the researcher must be able to see the reality or "proposed model" from the data, based on theoretical explanations or categories produced through comparisons of literature or experience against the actual data sets and, at the same time, the researcher must adhere to procedures that help to overcome biases.

Data Analysis

In this study, data analysis was carried out by treating each research respondent on its own merit, and then cross-participants' analysis followed. The researcher collated the number of answers on each research question answered. The empirical data obtained through the use of tape recorder from semi-structured interviews were transcribed verbatim, reviewed and coded to create data sets. In the process of reviewing transcribed data, responses were treated according to the research questions they responded to and in the process created data sets, categorised under the sub-headings of the question themes. The researcher then produced inductive themes according to each of the research questions. These themes were then compared with the outcome of the literature review and experience from the field, with the focus on overcoming biases in order to develop an agricultural knowledge support model.

Research Results and Discussion

Data were collected from the participants utilizing a semi-structured interview, observation and discussion. Participating emerging farmers expressed their inability to secure the needed agricultural knowledge support and the challenges involved in seeking for solutions from locations that are most often far from their base of farming operations. While participants' agricultural knowledge service providers expressed their inability to meet the heterogeneous need of the farmers and the lack of resources, such as human capital and transportation to move across farm locations that are geographically dispersed with uncommon needs, both expressing their willingness to contribute to any web-based platform that could foster interaction and collaborations between agriculture sector stakeholders.

Challenges militating against the use of traditional agricultural knowledge supports of SA emerging farmers

In this study, a strategy of agricultural knowledge support to enable South Africa's Black emerging farmers' transformation for optimal agricultural production was proposed, with the aim of providing one point of access, interaction and collaboration amongst farming stakeholders. This type of one point of access, interaction and collaboration on issues relating to farming support which are currently in disparate sources and locations, lacking the needed coordination that may enhance farmers' quick decision making is required. While knowledge support experts are often required to provide personalised support to farmers whose needs are heterogeneous in nature, however, there is no single platform, currently in existence, that could enable knowledge support experts to attend to individual farmers' needs. In other words, farmers will have to individually visit knowledge sources centres or the knowledge support sources directly or visit individual farms.

The existing use of information technology for agricultural knowledge support includes technologies such as radio, television, computers, video tapes, CD/DVD and even the World Wide Web; however, the lack of interaction amongst knowledge providers, brokers (extension workers) and users render them inadequate for the support of Black farmers whose educations in agricultural practices are limited in relation to market-oriented farming. Moreover, knowledge provision and support through the use of these media are often in a compressed format, requiring further interpretation and use linear approach for information gathered from various sources. The information is subsequently prepared through various stages of editing before publishing to the general public or recipients. Besides, individual farms' and farmers' attributes are never considered as relevant to the focus of published material.

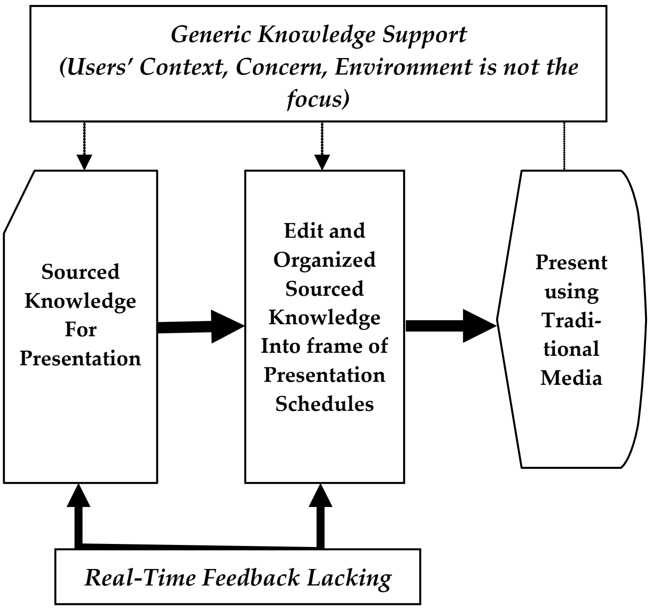

FIGURE 1.1 LINEAR APPROACH OF INFORMATION TECHNOLOGY KNOWLEDGE SHARING

Traditional media approach of knowledge provision depends on content management systems where authors and editors are in charge, without the necessary input from intended users (Kolbitch, 2007a).

This approach of knowledge support faces varied challenges including

- Knowledge is sometimes not delivered when required by the recipient
- Compression of knowledge to accommodate allotted space and time
- Knowledge is treated as a static commodity which may not change over time
- Knowledge is expert-centred; not user-centred or user-friendly
- Contextualization of knowledge requires further analysis and interpretation
- Since knowledge is generated from various sources before presentation, users are not likely to be able to confirm from the sources any challenges encountered during implementation
- Sources of knowledge are difficult to be verified before adoption.

ICT and the internet in particular are capable of providing the resources required to foster one point of access, interaction amongst farming stakeholders and the integration of disparate agricultural knowledge sources.

The empirical study clearly indicates the enormous need of user-centred agricultural knowledge support of South African Black farmers. Incidentally, the existing techniques of agricultural knowledge support are more appropriate and will add value to those with previous basic agricultural expertise who may require further understanding of specific farming practices. Thus, the study's empirical findings bring to the fore the importance of providing agricultural knowledge support infrastructure that could enhance direct interaction and collaborative effort of farming stakeholders, which could help in proffering solutions to farmers' varied problems and forming their farming educational foundation which currently lacks.

The educational task here is the ultimate goal of agricultural extension. This consists of communicating knowledge to farmers and helping them to adapt their farming methods to take full advantage of proven and acceptable technology that will improve the quality of rural life, as well as increasing the quantity and quality of a country's food, fibre and forestry production. But the effect of such communications, according to Singh (1981:2), Punya and Karl (2000:788), has not been quite as pronounced as one might expect. This is evidenced by inadequate knowledge, understanding, skills and sometimes negative attitudes relating to change that characterises small-scale farming communities.

Currently, according to Bembridge (1993:19), South Africa's extension services are ineffective due to management and institutional problems. A traditional farmers' day, in which experts address the farming community advising them what they should or should not do, is an inefficient way of meeting the farmers' needs (Oettle & Koelle, 2003:5). This is particularly the case with South Africa's emerging farmers who are the beneficiaries of land reform and distribution.

However, the study did not focus on the participants' familiarity with technology and their ability to navigate web-based knowledge support. It is assumed that given the participants' level of education, navigating web-based knowledge support should not be a problem because, as indicated in the findings, most of the participants have at one time or the other used the internet as a platform for searching for information.

While many of the existing techniques having been utilized to support emerging farmers could be described as traditional in agricultural practices all over the world, South African Black emerging farmers see them as inadequate to meet their aspiration and peculiarity; moreover, all the participating emerging farmers do not regard them as a viable means of agricultural knowledge support which could enhance their transformation to market-oriented farming.

For instance, most of the participants complain about the duration for which a mentorship programme is expected to last, since it is well acknowledged that farming seasons are difficult to predict and the hostile attitude of most farmers' mentors who often prefer to buy out the beneficiaries of land reform programmes. The well-publicised use of community radio and television broadcasts also come with their own challenges, since all programmes are expected to be pre-planned before being broadcast. Therefore, it may be difficult to include all situations, particularly the prevailing circumstances that the farmers are ~~as~~ at when the programmes are planned. Besides, interpreting research outcomes to the specific requirements of individual farmers within the broadcast duration is an unfeasible request.

Skills and experience required for subsistence farming are most often from farm owners, their families, and extension services, whereas market-oriented or commercial farming does not necessarily depend–on farm owner skills and experience, but rather on those of skilled farm employees. In South Africa, most skilled farm employees or about 85% of those that can be considered as highly educated in agricultural practices are not currently considered as emerging farmers. These groups of highly skilled farm employees are currently not obliged to work for Black emerging farmers. In other words, Black individuals that could be employed to work ~~in~~ on Black commercial farms are lacking and, at the moment, are not well versed in agricultural practices due to the segregation of the past (Donovan, 1994:275).

In order to promote collaboration in a user-centred approach, knowledge sharing, creation, integration, dissemination and technology transfer amongst service providers and emerging farmers, as well as the farmers' capacity building, a web-based knowledge-support infrastructure which has the potential of providing rich and complex shared knowledge, must be utilised.

Knowledge management, as pointed out by Kille (2005: 5), provides an integrated approach to identifying, managing, and sharing all of an organisation's knowledge assets, including the expertise and experience of individual employees, with the ultimate goal of helping an organisation attain its mission and goal.

The multi-disciplinary nature of the agricultural field~~,~~ contributes in no small way to the current challenges hampering Black emerging farmers' transformation, considering their background and their lack of formal agricultural education which, in effect, contribute to their inability to interpret and adopt scientific research findings. In order to proffer sustainable solutions to the multi-disciplinary challenges, a multi-disciplinary measure is needed, of which ICT platforms are capable of providing support.

In user-centred multidisciplinary research, as pointed out by Schumacher and Feuerstein (2007), new product or service development that fails, does so, not for lack of advanced technology, but because of a failure to understand real users' needs. There is a higher motivation in involving users at the earlier stages of the research and development process. This is in order to better understand the relationship between new innovative concepts and related users' behaviour~~,~~ within specific situations, as well as the potential cognitive workload in interpreting received signals.

Sharp, Rogers and Preece (2007:418) pointed out that the best way to ensure that development continues to take users' activities into account is to involve real users throughout development. This, according to Duin *et al* (2008), has proved to reduce business risks, such as the invention and acceptance of products and services and their application.

With the advent of Internet and the latest collaboration technologies, team work is no longer limited to a small group of people in an enterprise and it could spread to all stakeholder-suppliers, customers or other members of interest. Thus, groups of people organized in public self-organizing workgroups and specialized communities (communities of interest, and practice) generate knowledge that is shared, not individualized (Janev & Vranes, 2004:469). Internet and web technology in particular has undergone changes with initiatives, such as blogs, wikis, flickr and podcast as indicated by Kolbitch (2007); and ordinary users are enabled to get more involved in content creation.

Therefore, there is a need to approach South African Black farmers' transformation into market-oriented farming, with a user-centred multidisciplinary concept, and an integration of end-users and other stakeholders; the techniques of which, as indicated by Duin *et al* (2008), remain a difficult task.

In order to elaborate on this view, a knowledge-based model of an agricultural knowledge-support is presented in Figure 1.2. The diagram illustrates an interactive forum to enable collaborative discussion and shared meaning.

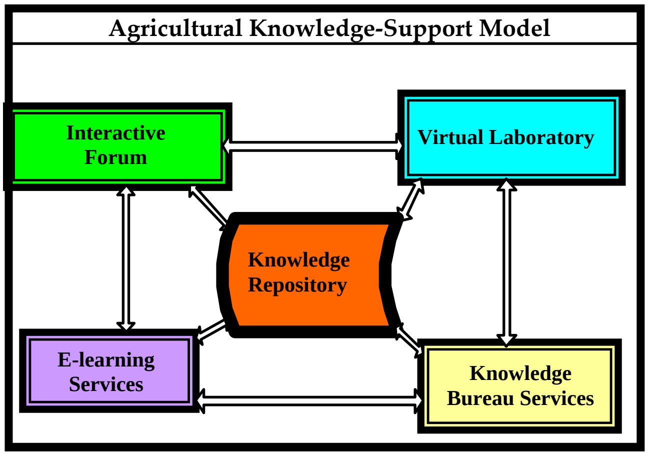

FIGURE 1.2 AGRICULTURAL KNOWLEDGE-SUPPORT PORTAL-MODEL *Source*: Akinsola (2009)

The virtual innovation laboratory aims to enhance joint research work amongst a virtual network of researchers, subject specialists and other agricultural role players. The knowledge bureau facilitates the linking of specialists and researchers to farmers or intermediaries (for example, extension agents or NGOs) who can help to resolve perennial issues in agricultural research. The knowledge repository facilitates access and knowledge re-uses, and the e-learning services are meant to host all learning resources, artefacts and tools for online education to interested farmers or their families. These will be deployed, based on web services, an ontological approach and the semantic web.

Conclusions

Bridging the knowledge gap of South African Black farmers using traditional agricultural knowledge support strategies is inadequate and inefficient. This is as result of the dual and complex nature of the South African agricultural sector, coupled with the intellectual competence required to function in a dynamic and multi-disciplinary market-oriented farming environment, where quality and quantity are dominant scales for economical viability. Agricultural education provision to Black farmers is a necessity to help develop their domain knowledge, and to improve their competency level. The required education can only be beneficial when provided simultaneously with active farming practices. In other words, Black farmers need a platform of dynamic knowledge support where personal attributes and unrestricted interactions with other stakeholders for clarification could be accomplished.

Bridging Black farmers' agricultural knowledge gap holds tremendous benefits, including sustainable employment, food security, poverty alleviation, an active manufacturing industry, an improved national economy and, probably, crime reduction. Moreover, consideration must be given to the complexity of harnessing agricultural knowledge from desperate sources to meet the heterogeneous Black farmers' needs.

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Genetic Identification of a Novel Locus (*LB2*) Regulates Bolting Time in *Beta vulgaris*

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Abstract

Bolting tendency in the facultative perennial species *Beta vulgaris*, which exhibits large intraspecific variation in bolting tendency, is a complex character governed by various environmental cues and multiple genetic factors. Significant variations in bolting time among annual *Beta vulgaris* ssp. *maritima* accessions were found. Three F2 populations derived from crosses between six annual beet accessions were analyzed for bolting tendency. Two populations (Bm38 and Bm49) exhibited phenotypic segregation ratios of 3:1 early-bolting and late-bolting which is expected for dominant-recessive inheritance of a monogenic trait. Phenotypic segregation ratio of the third population Bm49 was 15:1, early-bolting: late-bolting, which is expected for digenic dominant-recessive inheritance suggests the presence of a yet unidentified locus (*LB2*) which affects bolting time in annual *Beta vulgaris*.

Keywords

Beat Vulgaris; Sugar Beet; Bolting; Flowering; Floral Transition

Introduction

Sugar beet (*Beta vulgaris* L. ssp. *vulgaris*) is the only sucrose storing crop species that can be grown commercially in a wide variety of temperate climates. It accounts for about 30% of world sugar production and are important in Europe, North America, and increasingly in Asia, South America and North Africa. Cultivation of sugar beet in the tropical and subtropical regions, which are mostly developed countries, is a substantial goal (Abou-Elwafa *et al*., 2006; Abou-Elwafa *et al*., 2013).

Cultivated sugar beet is a biennial crop exhibits large intraspecific variation in vernalization requirement and life span, and includes annual accessions as well as long-lived, iteroparous perennials (Letschert, 1994;Hautekèete *et al*., 2002). In order to initiate bolting, sugar beet requires a combination of exposure to low temperatures between 2°C and 10º C (vernalization), followed by long-day conditions (Lexander 1980). In general, bolting time is accelerated and the number of bolters is increased as a result of vernalization (Sadeghian and Johansson 1993; Crosthwaite and Jenkins 1993; Abou-Elwafa *et al*., 2006). Significant variations have been observed among wild beet populations of the subspecies *Beta vulgaris* ssp. *maritima* in terms of life cycle and bolting behavior. These variations are latitude-dependent, and vary from perennial populations with vernalization requirement in northern areas to annual populations in the Mediterranean region (van Dijk *et al*., 1997). Variation in bolting time among wild beet populations was found to be mainly due to differences in their vernalization requirement. In contrast to biennial cultivated beets which have an obligate requirement for vernalization, annual wild beets bolt without prior vernalization. However, for sugar production early-bolting (bolting in the first growing season) is an undesirable because it drastically reduces root yield and interferes with mechanical harvesting, and breeders have successfully selected for the biennial habit (Jaggard and Werker, 1999; Rinaldi and Vonella, 2006).

Bolting tendency in sugar beet was suggested to be under the control of genes affected by vernalization and photoperiod and detected predominantly additive and dominant genetic effects, but also epistasis (Sadeghian *et al*., 1993). Owen *et al.* (1940) hypothesized the presence of a locus responsible for easy-bolting tendency in biennial beets, termed *B'*, which the authors suggested to be allelic to *B* in annual beets. The annual growth habit in *B. vulgaris* was shown to be controlled by a major dominant gene, referred to as the bolting gene *B*, which promotes the initiation of bolting in long days without vernalization (Munerati, 1931; Abegg, 1936). The *B* gene was genetically mapped by different mapping approaches to chromosome II of sugar beet (Boundry *et al*., 1994; El-Mezawy *et al*., 2002). Recently, a candidate of the *B* gene (*BvBTC1*) was recently cloned and functionally characterized (Pin *et al.* , 2012). Furthermore, three genes were identified to regulate bolting behavior in sugar beet; i) the locus *B2* which was mapped to chromosome VI of sugar beet and was shown to act epistatically to the B gene (Büttner *et al.*, 2010), ii) a locus acting independently from the *B* gene in regulating bolting time termed *B3* (Büttner *et al.*, 2010, and iii) *B4* locus which is genetically linked to the *B* gene on chromosome II and acting independently from the *B* gene in bolting regulation (Abou-Elwafa *et al.,* 2012). Shavrukow (2000) suggested that late-bolting in sugar beet is regulated by a gene termed *lb* which is linked to the monogermity gene on chromosome II of *Beta vulgaris*. The use of the facultative long-day plant *Arabidopsis thaliana* as a model has led to the identification of several putative *B. vulgaris* orthologs of flowering time genes in Arabidopsis, including *BvFL1* (an Arabidopsis *FLC* homolog), *BvCOL1*, *BvFLK* and *BvFVE* were identified and functionally characterized to be involved in the regulation of flowering time in sugar beet (Reeves *et al.*, 2007; Chia *et al.*, 2008; Abou-Elwafa *et al.*, 2010).

In the current study we used a forward genetic approach to further elucidate the genetic basis of the late-bolting phenotype in *B. vulgaris*. Annual *B. vulgaris* ssp. *maritima* genotypes which exhibited variations in bolting behavior were crossed together to produce F_2 populations segregating for bolting behavior which is essential for synchronization of bolting and flowering for hybrid seed production purposes. We hypothesized that the late-bolting phenotype is either: i) controlled by a single dominant gene, and a 3:1 phenotypic segregation ratio for bolting behavior (early-bolting *vs.* late-bolting) would be expected or ii) is genetically regulated by two unlinked loci in epistatic interaction. The expected phenotypic segregation for bolting behavior would also be 3:1, or iii) is a polygenic trait, and a deviation from the 3:1 phenotypic segregation ratio would be expected.

Materials and Methods

Plant Material

Annual *B. vulgaris* ssp. *maritima* accessions were collected from the Mediterranean coasts, and phenotyped for bolting time. Annual genotypes exhibited significant variations in bolting time were crossed together (Table 1; Figure 1). All crosses were conducted by bag isolation in the greenhouse. Cross progenies were identified phenotypically by hypocotyl color. F1 plants were propagated in the greenhouse, and selfed to produce F2 seed (Table 1). Three sibling F2 populations were used in the current study; i) population Bm07 consists of 93 individuals, ii) population Bm38 consists of 91 individuals and iii) population Bm49 which consists of 88 individuals.

TABLE 1 ANNUAL GENOTYPES USED FOR GENERATION OF F2 POPULATIONS

Annual pollinator	Annual seed parent	F1 plant selfed	F2 population
Bm11-01	Bm11-21	BmF1-07	Bm07
Bm11-03	Bm11-34	BmF1-38	Bm38
Bm11-07	Bm11-37	BmF1-49	Bm49

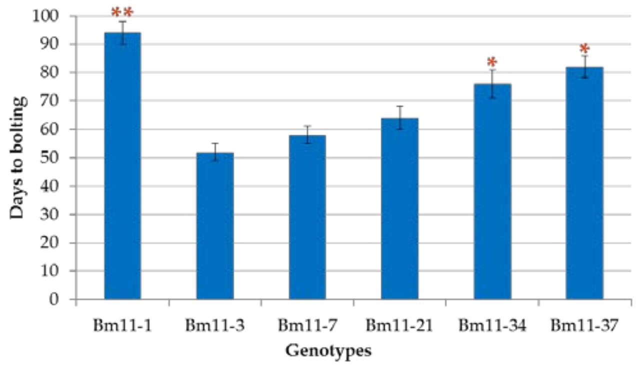

FIG. 1 PHENOTYPING OF ANNUAL *B. vulgaris* ssp. *maritima* ACCESSIONS. SIX ANNUAL ACCESSIONS WERE PHENOTYPED FOR THE ONSET OF BOLTING UNDER GREENHOUSE CONDITIONS. ASTRIKES INDICATE SIGNIFICANT DIFFERENCES AMONG ACCESSIONS AS CALCULATED BY ANALYSIS OF VARIANCE

Phenotypic Screening

The annual accessions Bm11-01, Bm11-03, Bm11-07, Bm11-21, Bm11-34 and Bm11-37 and F2 populations were phenotyped for the onset of bolting. Nineteen to twenty two plants from each accession were phenotyped. The F2 populations used in the current study are i) population Bm07consists of 93 individuals, ii) population Bm38 consists of 91 individuals and iii) population Bm49 which consists of 88 individuals. All experiments were carried out in a glasshouse with 21-25° C day and 15-18° C night temperatures, under long day conditions (16/8 h) with supplementary lighting using 400-w incandescent units. Seeds were sown on April 10, 2012, in 9 × 9 × 9 cm pots. The average light intensity at night above the soil was approximately 23917 lux. Plants were phenotyped every two to three days for onset of bolting (BBCH scale code 51; (Meier 2001)) until September 15, 2012.

Statistical Analysis

The statistical analysis (t-tests) and Chi square (χ^2) analysis was performed using SAS 9.1 (SAS Institute, Cary, NC, USA).

Results

Phenotypic Segregation for Late-Bolting

For each of the three crosses, 88 to 93 F2 plants were phenotyped for late-bolting behavior under long day conditions (early-bolting or late-bolting; Suppl. Tab. 1). All populations segregated for late-bolting behavior and contained both early-bolting and late-bolting individuals. In each population a distinct separation between the early-bolting individuals and the late-bolting ones was observed (Table 2; Figure 2). In the two populations Bm38 and Bm49, the phenotypic segregation ratios did not deviate significantly from the 3:1 segregation ratio of early-bolting and late-bolting plants expected for dominant-recessive inheritance of a monogenic trait, as tested by χ^2 analysis (Table 2). For the third population (Bm07), the null hypothesis of a 3:1 ratio was rejected at either α=0.05 or α=0.01, respectively. Meanwhile, segregation of early-bolting and late-bolting plants in the population Bm07 did not deviate significantly from a ratio of 15:1 (Table 2), which is expected for digenic dominant-recessive inheritance of the trait when only the double recessive genotype is late-bolting.

TABLE 2 PHENOTYPIC SEGREGATION FOR LATE-BOLTING BEHAVIOR IN F2 POPULATIONS

F2 population	Number of plants	EB[1]	LB[2]	χ2 test for H_0 = 3:1 (EB *vs.* LB)[3]	χ2 test for H_0 = 15:1 (EB *vs.* LB)[4]
Bm07	93	84	9	11.64**	1.86
Bm38	91	73	18	1.08	28.43**
Bm49	88	71	17	1.51	25.65**

[1] EB; early bolting plants
[2] LB; Late bolting plants
[3] H_0, null hypothesis for monogenic, dominant-recessive trait
[4] H_0, null hypothesis for digenic, dominant-recessive trait
** α=0.01

Variation in Bolting Time Among Annuals and F2 Populations

The six annual *B. vulgaris* ssp. *maritima* accessions used in generating the three F2 populations were phenotyped for bolting time. Significant differences in number of days to bolting among annual accessions were found (P<0.05; Figure 1). Accessions Bm11-01, Bm11-34 and Bm11-37 revealed a significant delay in bolting time compared to the remaining accessions.

The three F2 populations were phenotyped for bolting time (Figure 2; Suppl. Tab. 3). In general, population Bm38 and population Bm49 plants started to bolt earlier than population Bm07. The majority of early bolting plants of populations Bm38 and Bm49 started to bolt much earlier (at 6-9 weeks after sowing), while the late-bolting plants bolted much later (at 12-14 weeks after sowing; Figure 2). In population Bm07 the early bolting plants were approximately normally distributed with considerable delay in bolting time either within the early bolting or the late bolting subpopulations (Table 3; Figure 2). To test the significance of differences in bolting time between the early bolting and the late-bolting individuals within each population, T-test was performed for number of days to bolting between the two phenotypic classes (early bolting and late-bolting). In all of the three populations, highly significant differences in annual bolting time between the two phenotypic classes were observed as indicated by T-test. The mean of days to bolting for the late-bolting subpopulation was significantly higher than that of the early bolting subpopulation (Table 3).

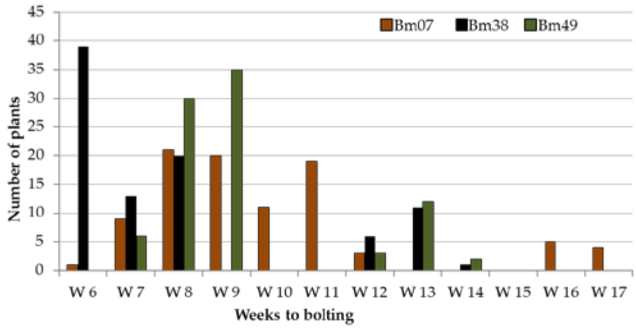

FIG. 2 BOLTING BEHAVIOR OF F2 POPULATIONS Bm07, Bm38 AND Bm49. 93, 91 AND 88 F2 PLANTS FROM Bm07, Bm38 AND Bm49 POPULATIONS WERE PHENOTYPED FOR ONSET OF BOLTING."WEEKS TO BOLTING" INDICATES THE WEEK, COUNTED FROM THE DATE OF SOWING, IN WHICH STEM ELONGATION BEGAN (i.e. week 6 corresponds to 36 to 42 days to bolting, etc.; s. Suppl. Table 1)

TABLE 3 T-TEST FOR NUMBER OF DAYS TO BOLTING IN F2 POPULATIONS

	Mean (± standard deviation) of days to bolting		
	Bm07	**Bm38**	**Bm49**
Early-bolting	68.89 (±9.71)	51.67 (±6.87)	63.94 (±4.54)
Late-bolting	108.22 (±2.63)	86.61 (±2.79)	88.47 (±3.52)
T value (P value)	12.05 (0.000)	21.07 (0.000)	20.80 (0.000)

Discussion

The genetic control of late-bolting phenotype were analyzed in three sibling F2 populations derived from a cross between four annual beet accession differed significantly in their bolting tendency. The major findings described in this study are: i) contrary to what had been thought, the *lb* locus is not the only locus underlying late-bolting phenotype in *B. vulgaris*, and ii) the discovery of a novel late-bolting locus (*LB2*) which regulates late-bolting behavior independently from the previously identified *lb* gene.

Two F2 populations, Bm38 and Bm49, behaved similarly in segregation for bolting time. The non-significant deviation of the pattern of phenotypic segregation of early bolting and late-bolting plants in populations Bm38 and Bm49 from 3:1 suggested that, according to our hypotheses (see Introduction), late-bolting behavior in both populations is either monogenically inherited (hypothesis i), or coregulated by two loci in epistatic interaction (hypothesis ii). In contrast to populations Bm38 and Bm49, the segregation data for population Bm07 indicating that the late-bolting phenotype control involves (at least) one additional late-bolting locus (*LB2*). The fact that the segregation ratio does not deviate significantly from 15:1 suggests that this locus is not linked to the *lb* gene and acts independently of *lb*, but like *lb* is also inherited in a dominant recessive manner.

In all populations, plants of within population could be classified into two distinct groups in terms of number of days to bolting (early-bolting and late-bolting plants). In general, late-bolting plants bolted substantially and highly significantly later than individuals of the early-bolting group (Table 3). Two lines of evidence emphasize that the late-bolting phenotype in BM07 is controls by two independent late-bolting genes. Firstly, in contrast to Bm38 and Bm49 bolting plants occurred in large excess of what would be expected for monogenic inheritance of this trait, and the observed segregation ratio matched more closely the expectation for digenic inheritance. Secondly, the early-bolting plants in population Bm07 bolted essentially late within a wide range of 41 days (from 45 to 86 days after sowing with an average of 68.89days) (Table 3; Suppl. Tab.). Similarly, the late bolting plants of Bm07 bolted substantially later than those of either the two other populations (with an average of 108.22 days). However, we also cannot exclude the possibility that the unexpectedly high phenotypic segregation ratio and the extremely late-bolting phenotype in this population are due to several quantitative loci (*BvBTC1, B2, B3* and *B4*: Pin *et al*. 2012, Büttner *et al*., 2010; Abou-Elwafa *et al*. 2012).

Conclusion

Our results add more complexity to the genetic control of late-bolting and floral transition in *B. vulgaris*. It was thought that the late bolting phenotype of *B. vulgaris* is genetically controlled by a single gene termed *lb* which was genetically mapped to chromosome II of *B. vulgaris* (Shavrukow 2000). A preliminary analysis of annual *B. vulgaris* ssp. *maritima* accessions for late-bolting suggests the presence of a unidentified locus (*LB2*) which is unlinked to the known late-bolting locus located on chromosome II (*lb*) and affects bolting time in annual *Beta vulgaris*. These genes may also prove to be candidate genes for the facilitation of induction and synchronization of bolting and flowering for hybrid seed production. A genetic map construction of population Bm49 is essential for QTL analysis to confirm the multigenic inheritance of the late bolting phenotype and to locate the genetic position of the identified *LB2* locus.

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