Agricultural Systems 123 (2014) 22–33

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Success of diagnostic approach to rainfed, wheat-based cropping systems in Western Australia

Darshan L. Sharma [a,*], Walter K. Anderson [b,c,1]

[a] Department of Agriculture and Food, 75 York Rd, PO Box 483, Northam, WA 6401, Australia
[b] Department of Agriculture and Food, 444 Albany Highway, Albany, WA 6330, Australia
[c] School of Plant Biology, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia

ARTICLE INFO

Article history:
Received 29 July 2012
Received in revised form 28 August 2013
Accepted 30 August 2013
Available online 4 October 2013

Keywords:
Farming system
Production constraints
Diagnostic approach
Weed management
Cereal cyst nematode
Ryegrass

ABSTRACT

Deterioration of crop yields due to exploitive cropping systems (CS) is a worldwide problem reducing profitability for farmers, food availability for consumers and inducing poor utilisation of rainfall. Following a diagnostic approach, likely constraints were identified and corresponding remedies tested in factorial experiments over three years at two sites in the central grain belt of Western Australia. The constraints at the first site (York, sandy clay loam soil) were high cereal cyst nematode (CCN), low cation exchange capacity (CEC) and soil compaction; and the remedies tested were CCN resistant cultivar, green manuring and deep ripping (DR). The constraints at the second site (Beverley, leaching prone sandy duplex soil) were high weed burden (ryegrass, *Lolium rigidum* L.), soil compaction, low pH and low CEC; and the remedies tested were repeated hay crops, deep ripping including lime application, and green manuring. Nitrogen applications on the cereal crops were split between sowing and after heavy rainfall events at the Beverley site.

The crop and variety choice was important at both sites, deep ripping was sometimes useful at Beverley but clearly detrimental at York. CEC was not increased using green manuring. Tactical N showed potential at the leaching site at Beverley where it often assisted in reducing the weed burden. We infer that a diagnostic approach can be successfully used to increase grain yield once constraints have been diagnosed and addressed. Constraints to yield at these sites were related and often interactive implying that addressing only one limiting factor may not be effective in improving yield in the short term. We found that the solution to CS problems can sometimes be as simple as variety replacement (for example, CCN resistant cultivar at York) but can often be complex as seen at the Beverley site.

It is concluded that where cropping systems in rainfed areas are not producing yields that approach the limits set by the rainfall, there is a need to devise a system of constraint prioritisation based on yield loss, causal hierarchy and hierarchy of consequences over time. It is suggested that farmers should test the diagnosed remedies on reference paddocks before they commit to heavy costs. Decisions about expensive remedies would ultimately lie in the balance between the costs of lost opportunity and implementation of the remedies.

1. Introduction

An overall enhanced productivity from cropping at the farm level is the focus of any cropping system (CS) research and comes through an efficient use of the available physical resource (Zandstra, 1979; Zandstra et al., 1981; ACIAR, 2010). An increase in resource use efficiency generally requires the implementation of several small to big changes in cultivation techniques, farming practices, machinery, and infrastructure. The big changes often face major hurdles to adoption as they are associated with trade-offs with other components of the system and may involve heavy costs which can potentially dampen economic viability of the enterprise (Brady, 1977). For example, a move from conventional to minimum soil tillage not only may require more powerful and expensive machinery but can also result in more intense and altered weed flora (Rusu et al., 2006). This implies that research aimed at advising simple and feasible recommendations that would cause minimum alterations to existing CS will have much greater grower interest, adoption and impact. One approach is to diagnose the defects in the current CS and apply the suggested remedies to efficiently lift productivity (Crozat et al., 1997; Dore et al., 1997, 2008; Wivstad et al., 2008) without having to adopt some very different alternative cropping system.

* Corresponding author. Tel.: +61 8 96902188.
E-mail addresses: darshan.sharma@agric.wa.gov.au (D.L. Sharma), wmanderson@bordernet.com.au (W.K. Anderson).
[1] Present address: 1084 Millinup Rd, Porongurup, WA 6324, Australia.

0308-521X/$ - see front matter Crown Copyright © 2013 Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.agsy.2013.08.007

Productivity of a CS is an outcome of the cropped genetics (G), environmental factors (E), crop management factors (M) and their interactions. In experiments with rainfed wheat the proportion of yield variance due to management often accounts for about twice the variance due to genotype (Anderson et al., 2005). Subsequent analysis of variation in wheat yield in Western Australia (WA) has revealed that the majority of this variation is caused by uncontrollable environmental factors of season and location and only about 10% is attributable to crop management (Sharma et al., 2008; Anderson, 2010). These results were, however, based on state-wide data across agro-climatic zones varying from a low of <200 mm to a high of >350 mm growing season rainfall, and soil types ranging from highly leached grey sands to fertile red brown loams. This implies that the contribution to yield variability of M and G would likely increase substantially if E was minimised by restricting analysis to specific regions. It is probably for this reason that Dore et al. (1997) proposed that "the study area in which a crop-yield diagnosis is performed should not be too large" and Wivstad et al. (2008) kept their organic farming CS studies specific to sites. Further, variance due to location was almost double the variance of season (Sharma et al., 2008). Therefore, restricting the diagnostic process to a given rainfall zone and soil type, but interrogating yield over more than one season, should form an effective diagnosis for any CS.

The process of diagnostic research has two main components: diagnosis and rectification. Diagnosis often starts with, and sometimes relies solely on interviews and surveys (Crozat and Chitapong, 1988; Singh et al., 2005; Yadav et al., 2006; Kataki et al., 2000) but quantitative analyses of the historical, experimental and simulation data definitely adds confidence to the process (Diouf, 1990; Thomas et al., 1995; Oosterom et al., 1996; Dore et al., 1997; Staggenborg et al., 2005). Further, in contrast to issue focussed traditional experiments, the CS research approach is essentially about integrating a range of relevant disciplines (Francis et al., 1995; Shreshta and Clement, 2003; Gliessman, 2004) and has an additional advantage when commercial farms are used as study sites (Drinkwater, 2002). Grower involvement is another factor known to substantially improve the outcome of the intended research (Forte-Gardner et al., 2004).

The CSs prevalent in all rainfall zones of the WA grain belt are primarily dominated by wheat. Rotations with legume crops and pastures are recommended but many farmers have been growing continuous cereals since prices for rotation crops have been poor, with the exception of canola (Robertson et al., 2010). Currently achieved yields are often much less than the rainfall-limited potential yields (Anderson, 2010) as calculated from French and Schultz (1984). Insofar as grain yield can be used as a surrogate for CS productivity, this existing yield gap demonstrates that prevalent CSs in the region have the potential to be improved substantially.

The overall purpose of this paper is to bring forth the critical components that would determine the success of diagnostic approach in narrowing down the yield gap of a given CS. Two CS experiments were conducted over three years at two sites in the high and medium rainfall zones in the central grain belt of Western Australia. An approach comprising constraint diagnosis followed by assessment of rectification treatments was used. The experiments were aimed to assess if the existing yield gap in the selected CSs can be narrowed by removing the diagnosed constraints and to determine the nature of interaction when more than one remedy are implemented simultaneously. The specific objective of these on–farm factorial experiments was to test the relative benefits of remedial or mitigating treatments applied to address the limiting factors suggested by paddock diagnosis based on soil and plant tests and farmer interviews. The indirect objective was to investigate the influence of tested remedies on changing the environmental situation so as to bring down the level of constraints.

2. Material and methods

2.1. Site selection

The most predominant production situation was identified for each of the high and medium rainfall zones using a scoping study (Anderson et al., 2007). The actual experimental sites were chosen to represent uniform areas on soil types common in the high and medium rainfall zones in the central grain belt after consultation with the collaborating farmers.

2.2. Constraint identification

Summary of the high risk diagnosed constraints and the considered possible solutions at York and Beverley sites are given in Tables 1 and 2, respectively. The identified constraint at York included a high cereal cyst nematode (CCN) (*Heterodera avenae* Woll.) egg number, high soil compaction, low cation exchange capacity (CEC) and a low soil available nutrient status (zinc and potassium). Given that nutrient deficiency is a season and crop specific constraint and is relatively much simpler to resolve as compared to other identified constraints, only the first three constraints were considered for further investigation. The site at Beverley had a very high weed burden of group A and B herbicides resistant ryegrass (*Lolium rigidum* L.), high soil compaction, low pH and a nutrient leaching sandy duplex soil type. Given that both the low pH and soil compaction cause root limitation, applying lime before deep ripping adds value to both the constraints (Gazey and Davies, 2009) and because the farmers often treat them together, these were clubbed together as one treatment. Following methods were used to identify these constraints.

2.2.1. Paddock records

Paddock records for rainfall, rotation and yield at the selected sites were procured from the respective farmers and comparison was made with the estimated potential yield using modifications of the French and Schultz (1984) equation.

2.2.2. Visual symptoms

Crop canopy was visually examined for physical appearance including plant height and head density in the season before the experiments were commenced.

2.2.3. Yield components

Yield components of the standing crop in five individual spots or from five good and bad paired patches where canopy was undulating or patchy, were recorded in 2005 following Sharma and Anderson (2004) and compared with the best parts of the same or adjoining paddock.

2.2.4. Root disease tests

Root samples from good and poor canopy patches were visually examined following Wallwork (1997) and soil samples were subjected to PreDicta B® test (Ophel-Keller et al., 2008; SARDI, 2012).

2.2.5. Soil physical and chemical tests

Samples from topsoil (0–10 cm) and subsoil (10–40 cm) layers were tested at the Australian Perry Agricultural Laboratory (South Australia) for soil organic carbon, total exchange capacity, pH, anions, cations and trace elements. Physical tests included soil compaction and bulk density measurements following Davidson (1965) and Blake (1965).