Short Communication

Indian Journal of Agricultural Sciences **88** (7): 1142–6, July 2018/Short Communication

Effect of integrated crop management modules on crop productivity and soil physico–chemical and biological properties under direct-seeded basmati rice (*Orzya sativa*)

KAJAL DAS[1], VIJAY POONIYA[2], ANIL K CHOUDHARY[3], K SWARNALAKSHMI[4], R S BANA[5], C M PARIHAR[6] and S K SARKAR[7]

ICAR–Indian Agricultural Research Institute, New Delhi 110 012

Received: 22 March 2018; Accepted: 24 April 2018

Key words: Dehydrogenase activity, Direct seeded basmati rice, Integrated crop management, Microbial biomass carbon, Soil organic carbon, Water stable aggregates.

Integrated crop management (ICM) concept integrates the best of modern cropping technology with suitable and appropriate blend of best farming practices which avoid wastage of costly external inputs, enhance energy efficiency, minimize pollution, and improve soil health and biodiversity on long–run (Choudhary *et al*. 2018). The basic principles of ICM are food and environmental security, economic viability, social acceptability, and food safety and quality. It may address natural resources conservation, generation and utilization for sustainability, resilience in production and sustained profitability (Kumar *et al*. 2016, Choudhary *et al*. 2018). In recent times due to sole use of synthetic chemical fertilizers leading to soil physico–chemical and biological degradation, higher water requirement for the conventional transplanting rice is alarmingly receding the ground water table in upper and trans Indo–Gangetic Plains Region (IGPR) by ~30–40 cm every year (Mahajan *et al.* 2012) and inefficient input use and irrational production practices resulting in decline in system productivity and resource–use–efficiency (Prasad 2005). Obviously, direct-seeded rice (DSR) is a potential alternative as it reduces labour requirement, cost and maintains similar grain yields as in case of transplanted rice (Ram *et al*. 2013, Choudhary and Suri 2013, 2014). It offers advantages like faster and easier planting, reduced labour and less drudgery, earlier crop maturity by 7–10 days, more efficient water use and less methane emission with higher profitability (Ram *et al*. 2013, Choudhary and Suri 2013, 2014). Therefore, it is quite possible that various management strategies in integrated manner under different crop establishment methods including zero-tillage (ZT), mulching and residue intervention may influence the nutrient dynamics, enhance productivity and profitability of rice. Keeping in view above facts, the approach to rice production needs to be redefined in the context of integrated resource management, high factor productivity and sustained farm profitability with safe food and environment. Thus, present study was conducted to quantify the influence of different integrated crop management (ICM) modules on crop productivity, soil physico–chemical and biological properties in direct-seeded basmati rice in north Indian plains region.

The experiment was conducted at ICAR–Indian Agricultural Research Institute, New Delhi (28°63’ N latitude; 77°15’ E longitude; 228.6 m altitude) during *kharif* 2016 (June–October) under a rice-wheat cropping system (RWCS). The soil of experimental site was sandy–clay–loam in texture with pH 7.9, oxidizable–SOC 0.503%, alkaline $KMnO_4$ oxidizable–N 169.5 kg/ha, 0.5 M $NaHCO_3$ extractable–P 11.5 kg/ha, and 1 N NH_4OAc extractable–K 275.3 kg/ha during initial year of study i.e., winter, 2014. The experiment was laid-out in randomized block design with 8 treatment combinations i.e. integrated crop management (ICM) modules with 3 replications. ICM modules include ICM_1: Conventional transplanting (TPR) + 100% of recommended dose of fertilizers @ 100:50:50 kg/ha N: P_2O_5: K_2O (RDF) + butachlor as pre-emergence (PE) @ 1 kg a. i./ha + 1 hand-weeding (HW); ICM_2: TPR + 75% RDF (N through zinc coated urea/ZCU + NPK bio-fertilizer/NPK-*bf*) + butachlor as PE @ 1 kg a. i./ha + 1 HW; ICM_3: Direct seeded rice (DSR) + 100% of RDF (N through ZCU) + pretilachlor as PE @ 0.75 kg a. i./ha followed by (*fb*) bispyribac-sodium @ 25 g a. i./ha as post-emergence (POE) at 25 DAS; ICM_4: DSR + 75% RDF + AM fungi (AMF) + NPK-*bf* + pretilachlor as PE @ 0.75 kg a. i./ha *fb* bispyribac-sodium @ 25 g a. i./ha as POE at 25 DAS + 1 HW; ICM_5: Zero tillage (ZT)- DSR + wheat residue

---

[1]Ph D Scholar, [2,5,6]Scientist, [3]Senior Scientist (e mail: anilhpau2010@gmail.com), Division of Agronomy, [4]Senior Scientist, Division of Microbiology, ICAR-Indian Agricultural Research Institute. [7]Scientist, Division of Agricultural Statistics, ICAR-Indian Agricultural Statistics Research Institute, New Delhi 110 012

@ 3 t/ha + 100% of RDF (N through ZCU) + glyphosate as pre-plant application (PP) @ 1 kg a. i./ha+ pretilachlor as PE @ 0.75 kg a. i./ha *fb* bispyribac-sodium @ 25 g a. i./ha as POE at 25 DAS; ICM_6: ZT-DSR + wheat residue @ 3 t/ha + 75% RDF + AMF + NPK-*bf* + glyphosate as PP @ 1 kg a. i./ha+ pretilachlor-PE @ 0.75 kg a. i./ha *fb* bispyribac-sodium @ 25 g a. i./ha as POE at 25 DAS + 1 HW; ICM_7: ZT-summer mungbean residue retention (SMB-RR) + ZT- DSR + wheat residue @ 3 t/ha + 75% RDF (N through ZCU) + glyphosate as PP @ 1 kg a. i./ha+ pretilachlor-PE @ 0.75 kg a. i./ha *fb* bispyribac-sodium @ 25 g a. i./ha as POE at 25 DAS; and ICM_8: ZT-SMB-RR + ZT- DSR + wheat residue @ 3 t/ha + 50% RDF + AMF + NPK-*bf* + glyphosate as PP @ 1 kg a. i./ha+ pretilachlor-PE @ 0.75 kg a. i./ha *fb* bispyribac-sodium @ 25 g a. i./ha as POE at 25 DAS + 1 HW. The need based disease and pest management practices were commonly followed in all the ICM modules. Rice variety '*Pusa Basmati 1509*' was sown using a seed rate of 30 kg/ha. The bulk density was calculated as follows:

$$\text{Bulk density(g/cc)} = \frac{\text{Mass of soil on oven dry weight basis(g)}}{\text{Core volume(cc)}}$$

Water stable aggregates (WSA) were calculated according to Kemper (1966) using the formula:

$$\text{WSA(\% of soil)} = \frac{\text{Weight of dry aggregates} - \text{sand}}{\text{Weight of dry soil} - \text{sand}} \times 100$$

The soil moisture content was calculated as follows:

$$\text{Soil moisture content(\%)} = \frac{\text{Fresh weight of soil(g)} - \text{oven dry weight of soil(g)}}{\text{Oven dry weight of soil(g)}} \times 100$$

Collected soil samples were analyzed for organic carbon by wet digestion method (Walkley and Black 1934), available nitrogen by alkaline permanganate ($KMnO_4$) procedure (Subbiah and Asija 1956), available phosphorus in soil (Olsen *et al.* 1954) and available potassium by flame photometer. Microbial biomass carbon in soil samples was estimated by the method described by Vance *et al*. (1987). Dehydrogenase activity of soil samples was estimated by the method described by Casida *et al*. (1964). The activity of alkaline phosphatase in soil was assayed by the method developed by Tabatabai and Bremner (1969).

Current study revealed that rice productivity (Fig 1), soil physico–chemical and biological properties were found significant under different ICM modules (Table 1 to 3). The significant difference in grain yield was recorded and significantly higher in ICM_7 (4.03 t/ha) a CA based ICM module which was followed by ICM_8 (3.87 t/ha) and ICM_1 (3.68 t/ha). Soil bulk density (SBD) increased with increase in soil depth in the current study. After two years of this experimentation, in upper soil layer (0–5 cm and 5–15 cm depth), the higher SBD values were recorded in puddled/ conventional plots without residue (ICM_1 and ICM_2) and lower SBD values in residue retained plots (ICM_5 to ICM_8). The residue management in ZT plots (ICM_5 to ICM_8) had greater impact on SBD in the 0–15 cm soil layer as compared with no residue added plots, as the soil surface retained crop residues undergo series of physical churning with soil and microbe facilitated decomposition which improves the soil structure and reduces SBD which in turn increases the infiltration and water retention, improves soil aeration and moderates the soil temperature (Choudhary *et al*. 2008). Husnjak *et al.* (2002) have also studied that conservation tillage give more favorable soil physical environment for rice growth and development than conventional tillage. The influence of different ICM modules on water stable aggregates at the soil depths was found significant. ICM_7 exhibited higher percentage of water stable aggregates followed by ICM_8, ICM_6 and ICM_5, respectively; indicating that continuous residue retention improved WSA (>0.20 mm) while SBD got significantly reduced in long–run. Soil moister content was higher under zero–tilled residue retained plots over CT based ICM modules at different soil depths. Soil moisture content at 0–5 cm and 15–30 cm soil depths were found non–significant but at 5–15 cm depth was found significant.

The experiment revealed that SOC got improved over

Table 1 Influence of ICM modules on soil physical properties after harvest of rice crop under rice-wheat cropping system (RWCS)

Treatment	Soil bulk density (g/cc)			% WSA (> 0.20 mm)			Soil moisture content (%)		
	0–5 cm	5–15 cm	15–30 cm	0–5 cm	5–15 cm	15–30 cm	0–5 cm	5–15 cm	15–30 cm
ICM_1	1.53	1.56	1.60	48.9	47.2	46.2	13.9	13.1	14.8
ICM_2	1.52	1.55	1.60	49.3	47.3	46.5	13.8	12.7	14.9
ICM_3	1.52	1.53	1.57	48.9	47.4	46.6	13.3	13.1	14.6
ICM_4	1.51	1.53	1.57	49.5	47.4	46.7	13.3	13.2	14.6
ICM_5	1.50	1.52	1.56	49.6	47.6	46.2	13.2	14.1	14.5
ICM_6	1.50	1.52	1.56	49.8	47.5	46.9	13.2	14.0	15.2
ICM_7	1.49	1.52	1.55	51.2	49.3	48.9	13.5	15.2	15.3
ICM_8	1.49	1.52	1.56	50.1	47.8	47.2	13.0	15.1	15.3
SEm±	0.01	0.01	0.008	0.42	0.17	0.32	0.43	0.56	0.30
CD (P=0.05)	0.02	0.03	0.023	1.29	0.53	0.97	NS	1.721	NS

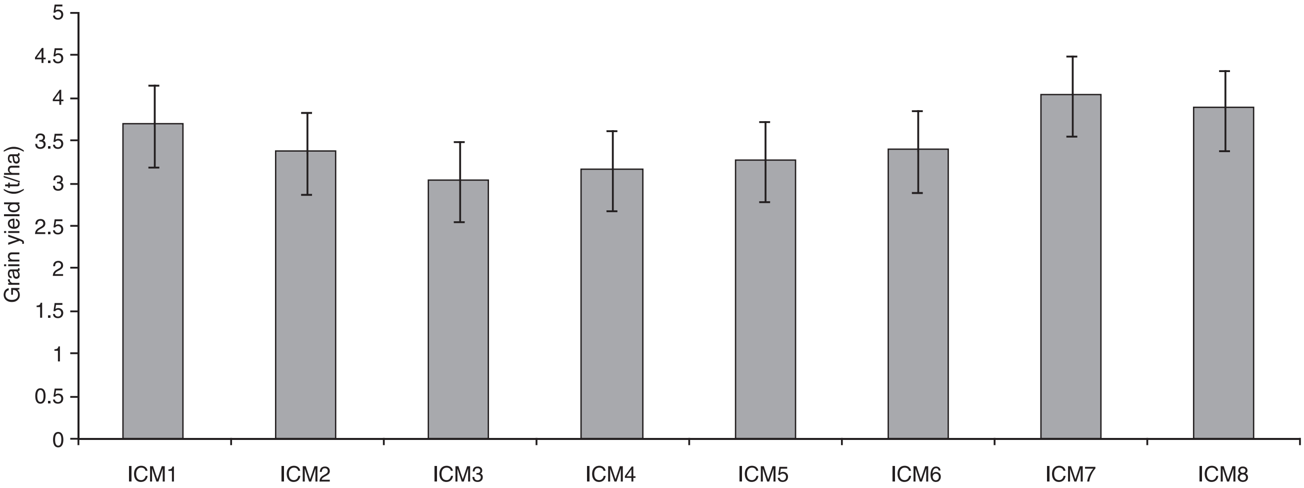

Fig 1 Influence of ICM modules on grain yield (The vertical bars indicate CD at P = 0.05).

Table 2 Influence of ICM modules on soil chemical properties after harvest of rice crop under RWCS

Treatment	Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)			SOC (%)		
	0–5 cm	5–15cm	15–30 cm	0–5 cm	5–15 cm	15–30 cm	0–5 cm	5–15 cm	15–30 cm	0–5 cm	5–15 cm	15–30 cm
ICM$_1$	169.8	163.2	153.8	12.51	11.47	10.84	270.4	262.0	257.2	0.51	0.50	0.46
ICM$_2$	170.6	163.9	152.5	12.29	11.41	10.53	272.3	265.7	257.5	0.51	0.49	0.46
ICM$_3$	170.5	163.8	156.2	12.08	11.90	11.11	272.9	266.2	258.4	0.51	0.50	0.47
ICM$_4$	169.1	165.7	152.6	12.06	11.61	11.03	270.5	264.0	255.1	0.51	0.50	0.47
ICM$_5$	176.4	169.8	162.9	13.80	13.28	11.88	281.9	275.0	267.2	0.52	0.51	0.47
ICM$_6$	177.7	170.7	158.5	13.62	13.16	11.62	280.3	274.3	266.7	0.52	0.51	0.47
ICM$_7$	185.9	181.3	169.1	13.93	13.81	12.19	289.0	280.7	270.6	0.55	0.54	0.48
ICM$_8$	181.0	175.0	158.3	13.65	12.89	11.82	290.3	281.3	272.5	0.54	0.53	0.48
SEm±	3.41	3.17	3.11	0.36	0.24	0.25	2.46	2.41	1.87	0.009	0.006	0.009
CD (P=0.05)	10.36	9.63	9.44	1.08	0.71	0.77	7.48	7.32	5.69	0.027	0.019	NS

Table 3 Influence of different ICM modules on soil microbiological properties after harvest of rice crop under RWCS

Treatment	Alkaline phosphatase activity (µg p–nitrophenol/g soil/hr)			Dehydrogenase activity (µg TPF/g soil/24 hr)			SMB–C (µg carbon/g soil)		
	0–5 cm	5–15 cm	15–30 cm	0–5 cm	5–15 cm	15–30 cm	0–5 cm	5–15 cm	15–30 cm
ICM$_1$	59.2	48.8	28.3	30.6	17.4	7.1	70.7	93.6	36.1
ICM$_2$	46.6	39.7	29.3	24.6	18.6	8.1	82.5	164.3	42.0
ICM$_3$	72.4	40.6	32.3	35.9	19.2	7.9	115.6	180.8	64.8
ICM$_4$	51.4	53.0	26.3	34.8	23.4	7.9	96.1	156.5	39.1
ICM$_5$	78.9	57.2	49.8	28.7	30.6	7.6	111.2	191.4	52.5
ICM$_6$	80.7	75.7	31.4	32.0	29.2	8.7	130.5	182.8	85.1
ICM$_7$	82.9	77.6	39.2	35.8	38.9	10.8	175.4	201.2	128.7
ICM$_8$	91.5	54.8	42.2	38.7	33.8	8.1	168.8	198.2	125.3
SEm±	4.09	4.87	4.60	1.97	3.60	0.66	13.14	20.28	7.22
CD (P=0.05)	12.39	14.79	13.96	5.98	10.93	2.00	39.8	61.5	21.8

the initial SOC status with significant improvement in 0–5 cm and 5–15 cm soil layers; however, the influence in 15–30 cm layer was found non–significant. The SOC nominally increased under zero–tilled residue retained plots supplied with wheat crop residue @ 3 t/ha (ICM_5 to ICM_8) as well as under mungbean residue retention plots (ICM_7 and ICM_8). The results showed that soil N considerably improved over the initial status and the influence of different ICM modules on the soil available N was also found significant. It's clear that ICM_7 module had the highest available soil N in different soil depths. In general, N content decreased with soil depth (0–30 cm), values ranged from ~169–186, 163–181 and 152–169 kg/ha in 0–5 cm, 5–15 cm and 15–30 cm, respectively. A significant increase in available phosphorous was recorded in 0–30 cm soil depths compared to initial status. The residue retained plots (ICM_5 to ICM_8) had higher available soil phosphorous compared to conventional plots (ICM_1 to ICM_2). In general, P content decreased with soil depth (0–30 cm), values ranged from 12.1–13.9, 11.4–13.9 and 10.5–12.2 kg/ha in 0–5, 5–15 and 15–30 cm, respectively. The study revealed that soil K improved over the initial status and the influence of different ICM modules on the soil available K (0–30 cm depth) was found significant. In general, available K content decreased with soil depth (0–30 cm), values ranged from 270.4–290.3, 262–281 and 257–272 kg/ha in 0–5, 5–15 and 15–30 cm, respectively. The SOC increased under zero–tilled with residue retention plots, due to beneficial effect of retaining crop residues in the field in a wide variety of crops, i.e. wheat and mungbean, which increased the organic matter, aggregation, water holding capacity and infiltration (Das *et al*. 2014, Harish *et al.* 2017). ICM_7 a CA based ICM module had the highest NPK build–up. Similar results were found in case of SOC build–up. Application of 100% RDF made an appreciable but non–significant build–up of these nutrients in the soil over 75% RDF + AM fungi + NPK-*bf*, indicating that, AM fungi has some vital role in meeting the plant nutrient requirements especially P through various mechanisms (Kumar *et al.* 2015). The AM fungi alongwith NPK-*bf* also had some synergetic interactions on enhanced nutrient acquisition and availability in soil, thus, improving soil fertility (Harrier and Watson 2003).

In general, ICM modules significantly influenced soil microbial biomass carbon (SMB–C) at different soil depths. SMB–C significantly higher under CA based ICM modules over the CT based ICM modules. The highest SMB–C was registered in ICM_7 followed by ICM_8 at 0–30 cm soil depth, which might be due to moisture content in 5–15 cm soil layer. The percent increase in SMB–C in ICM_7 was to the tune of 3.90 and 34.3% (0–5 cm depth), 1.41 and 10.1% (5–15 cm depth), 2.71 and 47.4% (15–30 cm depth) over ICM_8 and ICM_6. The dehydrogenase activity (DHA) and alkaline phosphatase activity (APA) registered significant differences among all the ICM modules at 0–30 cm soil depth. ICM_8 module registered significantly highest values of dehydrogenase and alkaline phosphatase at 0–5 cm soil depth while ICM_7 exhibited higher values at 5–15 and 15–30 cm soil depths. Overall, SMB–C, DHA and APA significantly higher under CA based ICM modules (ICM_5–ICM_8) over the CT based modules (ICM_1–ICM_4) up to 30 cm soil depth. Better soil aeration and improved rhizospheric environment coupled with higher root biomass under ZT plots over CT; might have also been the appropriate triggering force for improved soil biological activities in the present study (Ram *et al*. 2013). Residue retention leads to improved SOM which is a precursor for microbial activities in the soil, thus, influencing the SMB–C which in turn positively affected DHA and APA in the soil (Paul *et al*. 2014).

SUMMARY

The findings clearly indicate that residue-retained ZT based integrated crop management practices alongwith suitable blend of nutrients and weed management holds feasible option to enhance soil physico–chemical and biological properties for improving the soil health and quality in direct-seeded rice. The ICM_7 module, i.e. zero-till (ZT)-summer mungbean residue retention (SMB-RR) + ZT- direct seeded rice (DSR) + wheat residue @ 3 t/ha + 75% of RDF (N through ZCU) + glyphosate as pre-plant (PP) @ 1 kg a.i./ha + pretilachlor @ 0.75 kg a.i./ha followed by bispyribac-sodium @ 25 g a.i./ha + need based water management had the highest NPK build–up and soil organic carbon build-up besides improved soil physico-chemical and biological properties which ultimately led to improved rice productivity in north Indian plains region.

REFERENCES

Cassia Jr L E, Klein D A and Santoro T. 1964. Soil dehydrogenase activity. *Soil Science* **93**: 371–6.

Choudhary A K and Suri V K. 2013. *'On-farm'* participatory technology development effects on resource conservation technologies in rainfed upland paddy in Himachal Pradesh, India. *Communications in Soil Science and Plant Analysis* **44**(17): 2605–17.

Choudhary A K and Suri V K. 2014. Integrated nutrient management technology for direct-seeded upland rice (*Oryza sativa*) in northwestern Himalayas. *Communications in Soil Science and Plant Analysis* **45**(6): 777–84.

Choudhary A K, Bana R S and Pooniya V. 2018. *Integrated Crop Management Practices for Enhancing Productivity, Resource Use Efficiency, Soil Health and Livelihood Security*, pp 229. ICAR. Indian Agricultural Research Institute, New Delhi.

Choudhary A K, Thakur R C and Kumar N. 2008. Effect of integrated nutrient management on soil physical and hydraulic properties in rice–wheat crop sequence in north-western Himalayas. *Indian Journal of Soil Conservation* **36**(2): 97–104.

Das T K, Bhattacharyya R, Sudhishri S, Sharma A R, Saharawat Y S , Bandyopadhyay K K , Sepat S, Bana R S, Aggarwal P, Sharma R K, Bhatia A, Singh G, Datta S P, Kar A, Singh B, Singh P, Pathak H, Vyas A K and Jat M L. 2014. Conservation agriculture in an irrigated cotton–wheat system of the western Indo-Gangetic Plains: Crop and water productivity and economic profitability. *Field Crops Research* **158**: 24–33.

Harish M N, Choudhary A K, Singh Y V, Pooniya V, Das A, Varatharajan T and Babu S. 2017. Effect of promising rice (*Oryza sativa* L.) varieties and nutrient management practices on growth, development and crop productivity in eastern

Himalayas. *Annals of Agricultural Research* **38**(4): 375–84.

Harrier L A and Watson C A. 2003. The role of arbuscular mycorrhizal fungi in sustainable cropping systems. *Advances in Agronomy* **42**: 185–225.

Husnjak S, Filipovic D and Kousutic S. 2002. Influence of different tillage systems on soil physical properties and crop yield. *Rostlina Vyroba* **48**(6): 249–54.

Kemper W D and Koch E J. 1966. Aggregate stability of soils from the western portions of the United States and Canada. *USDA Technical Bulletin* 1355.

Kumar A, Choudhary A K and Suri V K. 2015. Influence of AM–fungi and applied phosphorus on growth indices, production efficiency, phosphorus–use efficiency and fruit–succulence in okra (*Abelmoschus esculentus*)–pea (*Pisum sativum*) cropping system in an acid Alfisol. *Indian Journal of Agricultural Sciences* **85**(8): 1030–7.

Kumar S, Rana D S, Palsaniya D R and Choudhary A K. 2016. Integrated crop management. (In) *Modern Concepts of Agronomy*, pp 324–38. Rana *et al*. 2016 (Eds). Indian Society of Agronomy Publication, New Delhi.

Mahajan G, Singh K and Gill M S. 2012. Scope for enhancing and sustaining rice productivity in Punjab (food bowl of India). *African Journal Agricultural Research* **7**: 5611–20.

Olsen S R, Cole C V, Watanabe F S and Dean L. 1954. Estimation of available phosphorus in soil by extraction with sodium carbonate. USDA, Washington, p 933.

Paul J, Choudhary A K, Suri V K, Sharma A K, Kumar V and Shobhna. 2014. Bioresource nutrient recycling and its relationship with biofertility indicators of soil health and nutrient dynamics in rice–wheat cropping system. *Communications in Soil Science and Plant Analysis* **45**(7): 912–24.

Prasad R. 2005. Rice-wheat cropping system. *Advances in Agronomy* **86**: 255–339.

Ram H, Yadvinder–Singh, Saini K S, Kler D S and Timsina J. 2013. Tillage and planting methods effects on yield, water use efficiency and profitability of soybean–wheat system on a loamy sand soil. *Experimental Agriculture* **49**(4): 524–42.

Subbaiah B V and Asija C L. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Current Science* **25**: 415–26.

Tabatabai M A and Bremner J M. 1969. Use of P–nitrophenyl phosphate for assay of soil phosphatase activity. *Soil Biology and Biochemistry* **1**: 301–7.

Vance E D, Brookes P C and Jenkinson D S. 1987. An extraction method for measuring soil microbial biomass carbon. *Soil Biology and Biochemistry* **19**: 703–4

Walkley A and Black I A. 1934. An examination of the dagtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**(1): 29–38.